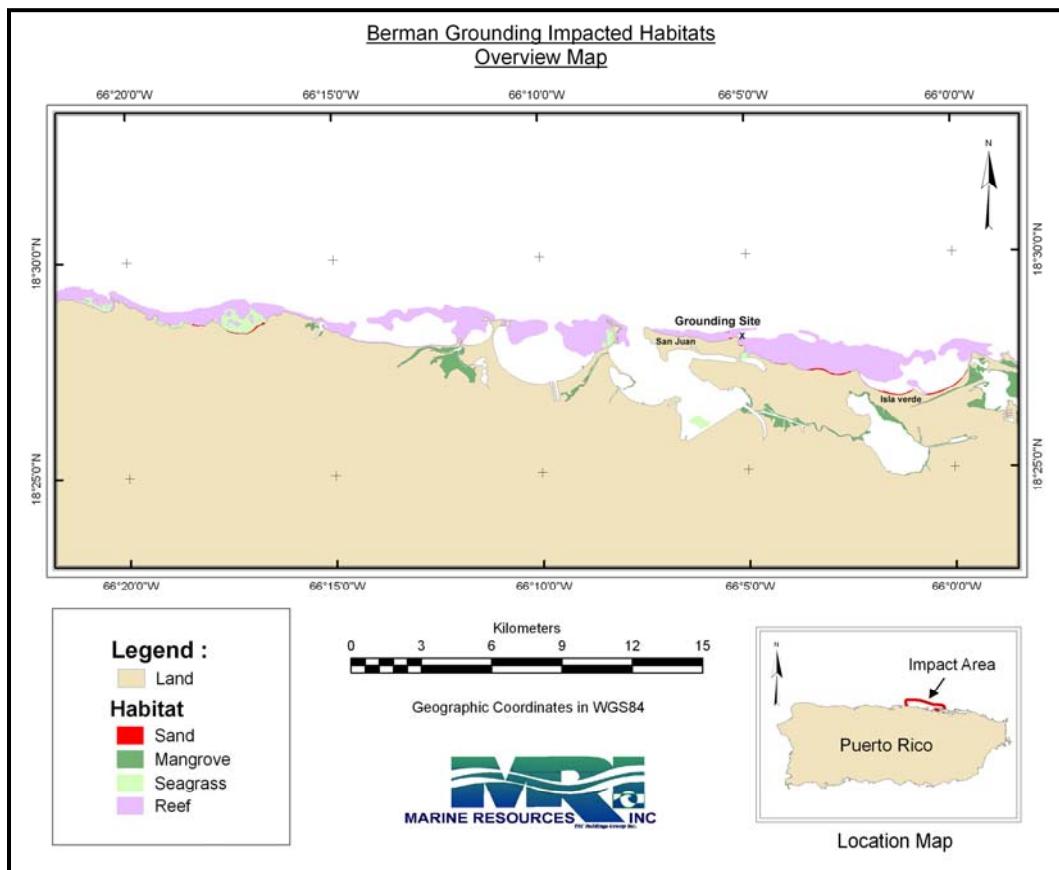


Análisis de Aptitud del Hábitat: Compensación por Concepto de Arrecife Dañado en Apoyo de la Planificación de la Restauración en el Caso del Derrame de Petróleo de la Embarcación Berman, San Juan, Puerto Rico

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1.0 INTRODUCCIÓN

1.1 Antecedentes

En la mañana del 7 de enero de 1994, el cable de remolque del remolcador Emily S. sufrió una ruptura, haciendo que la barcaza tanque Morris J. Berman quedara a la deriva empujada por el viento y la corriente durante aproximadamente una hora antes de que encallara. La embarcación, cargada con 35.000 bbl de petróleo Nr. 6, encalló en un arrecife eolianita de fondo duro aproximadamente a 274 m (300 yardas) frente a la costa donde se encuentra la Playa Escambrón en San Juan, Puerto Rico (Figura 1). La encalladura de la embarcación en el arrecife eolianita hizo que siete de los nueve tanques sufrieran una ruptura, lo que ocasionó el derrame de aproximadamente 17.000 bbl de petróleo en el arrecife y en las áreas cercanas a la costa (Applied Science Associates 1994). La embarcación permaneció encallada por algo más de una semana, siendo puesta a flote y remolcada a un sitio donde fue hundida el 15 de enero de 1994. Se reportó que el petróleo derramado afectó a más de 30 millas de línea costera a lo largo de la costa norte de Puerto Rico (Applied Science Associates 1994). El peso de la embarcación escarificó el arrecife eolianita y dislocó el substrato de roca, creando rocas sueltas y escombros (Hudson y Goodwin 1995); se estimó que el área afectada abarcó 1.009 m².

1.2 Objetivo

Un acuerdo de indemnización entre el Gobierno de Estados Unidos, el Estado Libre Asociado de Puerto Rico y las partes responsables concernientes a la encalladura del Morris J. Berman resolvieron las reclamaciones por los daños a los recursos naturales resultantes. La Administración Nacional de los Océanos y de la Atmósfera (NOAA), el Departamento de Comercio de los Estados Unidos, el Servicio Nacional de Parques, una entidad del Departamento del Interior de los Estados Unidos, y el Departamento de Recursos Naturales y Ambientales de Puerto Rico, como fiduciarios de los recursos naturales, tienen la responsabilidad de evaluar la amplitud de los daños a los recursos, planificar proyectos de restauración, preparar un plan de restauración e implementar dicha restauración. La restauración *in situ* del arrecife dañado no se considera factible debido a la poca profundidad y a las condiciones marítimas poco favorables. Los Fiduciarios compensarán los servicios perdidos del área dañada realizando una restauración compensatoria fuera del sitio, ya que la restauración *in situ* no es opción. Según la Orden de Tarea Nr. 8 del contrato WC133F-04-CQ0003 de la NOAA y en apoyo del Consejo de Fiduciarios, Tetra Tech EM, Inc. subcontrató a Marine Resources Inc. (MRI) la tarea de realizar un Análisis de Aptitud del Hábitat (HSA) para identificar hábitat marinos locales que podrían ser utilizados para una restauración compensatoria. El objetivo del Análisis de Aptitud del Hábitat es evaluar y clasificar varios hábitat marinos con respecto a las funciones que ofrecen para determinar la aptitud de proporcionar compensación ecológica para los recursos perdidos asociados con la encalladura del Morris J. Berman a lo largo de la costa de Puerto Rico.

Un total de 183 organismos, documentados gracias al proyecto de investigación bibliográfica, están presentes en el hábitat de arrecife eolianita y se considera que han sido dañados directa o indirectamente por la encalladura del Morris J. Berman. Las especies, cuya presencia se ha documentado en el hábitat eolianita, se pueden describir mediante la función principal que proporcionan al ambiente: 1) productores primarios, 2) animales estructurales, 3) herbívoros

(invertebrados y vertebrados), y 4) predadores (invertebrados y vertebrados). De las 183 especies cuya presencia se ha documentado en hábitat de arrecifes eolianitas, 8% es productor primario, 29% es animales estructurales, 11% es herbívoro y 52% es predador. Una descripción más detallada de los organismos y de las funciones que proporcionan dentro de cada categoría se ofrece en la Sección 3.3.

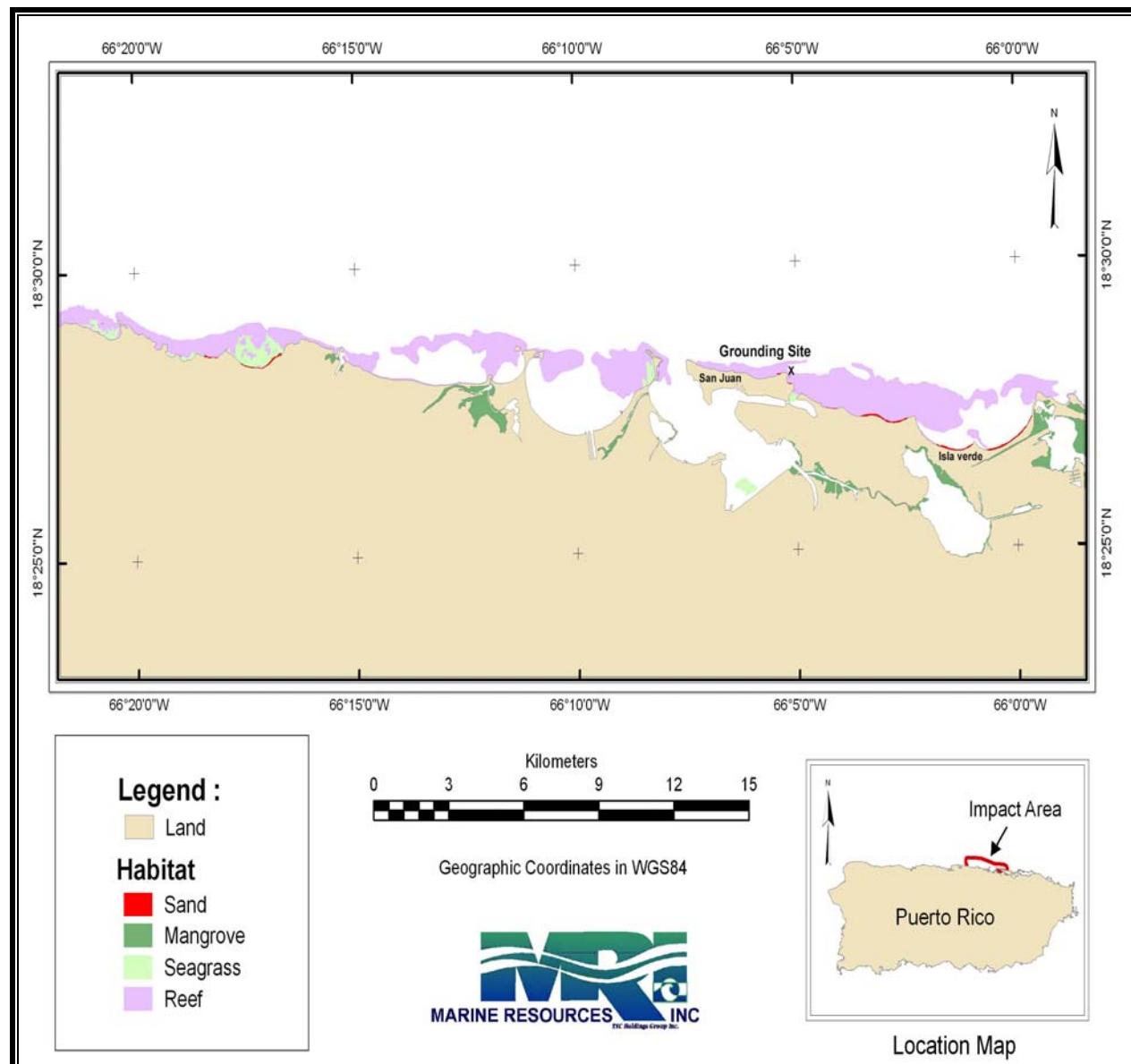


Figura 1. Ubicación del sitio donde encalló el *Morris J. Berman* con relación a San Juan

2.0 MÉTODOS

La evaluación de los beneficios ecológicos potenciales asociados con la restauración compensatoria del hábitat se realizó a través del análisis de artículos y documentos técnicos publicados. El principal objetivo de esta evaluación fue comparar las funciones ecológicas proporcionadas por el hábitat de arrecife eolianita con las funciones ecológicas que probablemente se añadirían debido a la creación (Powers et al., 2003), restauración (Peterson et al., 2004) y/o protección (Sperduto et al., 2003) de hábitat alternativos. Según se especifica en la Descripción de Trabajo, los hábitat evaluados sobre la base de las funciones que brindan son los siguientes:

- 1) *arrecife eolianita* – substrato litificado situado en aguas cuya profundidad oscila entre 0 y 5 m, característico de la línea costera de San Juan, con su geomorfología relacionada estrechamente con la erosionabilidad de la formación rocosa;
- 2) *fondo duro en aguas poco profundas* – substrato consolidado que sirve de sustento a una comunidad biológica dominada por organismos sésiles incrustados y situados en aguas de 5 a 10 m de profundidad;
- 3) *fondo duro en aguas profundas* – substrato consolidado que sirve de sustento a una comunidad biológica dominada por organismos sésiles incrustados y situados en profundidades superiores a 10 m;
- 4) *manglares* – sistema de raíz fúlerea sumergido del mangle rojo (*Rhizophora mangle*) y substrato enlodado adyacente en profundidades de 0 a 2m; y
- 5) *lechos de hierbas marinas* – conjunto de multiespecies de hierbas marinas, a menudo dominadas por una fuerte presencia de *Thalassia testudinum* (turtle grass), presentes en ensenadas con profundidades de 0 a 5 m.

Los datos sobre la comunidad biológica sustentados por el hábitat de arrecifes artificiales no estaban disponibles para la región de interés; en consecuencia, el arrecife artificial no se incluyó como hábitat específico en el Análisis de Aptitud del Hábitat. Sin embargo, la creación de hábitat de arrecifes artificiales podría ser la alternativa preferida de restauración compensatoria para el fondo duro en aguas poco profundas y los hábitat de fondos duros de aguas profundas. Aunque no había disponible ninguna información específica sobre la costa norte de Puerto Rico concerniente al hábitat de arrecifes artificiales, existe una base bibliográfica substancial que compara la estructura de la comunidad biológica entre arrecifes naturales y artificiales. La mayoría de esta bibliografía se centra en especies predadoras (peces e invertebrados móviles). El consenso que emerge de esta bibliografía es que los arrecifes artificiales diseñados para elevar al máximo la complejidad estructural y alivio pueden sustentar diversas especies de peces y de conjuntos epibénticos (Sherman et al., 2002; Hixon y Beets, 1989; Hudson et al., 1989; Gorham y Alevizon 1989). Los arrecifes artificiales diseñados para proporcionar refugio mediante la inclusión de pequeños huecos en el concreto podrían mejorar la supervivencia de peces de aletas importantes desde el punto de vista recreativo y comercial (Hixon y Beets 1989; Beets y Hixon 1994). Rilov y Benayahu (2000) reportaron que diseñaron y supervisaron estructuras de arrecifes artificiales en el Mar Rojo de Eliat que servían de sustento a un conjunto de peces más diverso que los hábitat de fondo duro natural de los alrededores. Resultados que indican comunidades de peces similares entre arrecifes naturales y artificiales se han reportado en el caso de arrecifes artificiales construidos en aguas costeras de los Estados Unidos (véase Ambrose y Swarbrick

1989). Estudios que examinan la dieta y el crecimiento de los peces también han demostrado un alto grado de similitud entre hábitat artificiales y naturales (Donaldson y Clavijo, 1994; Vose y Nelson 1994; Lindquist et al. 1994). Basándonos en nuestro análisis de la bibliografía, se asume que un sistema de arrecife artificial situado dentro de un biotope específico y diseñado para imitar el hábitat de fondo duro natural local funcionaría, después de un breve período de sucesión (~5 years), de manera similar al fondo duro natural para cuya imitación fue diseñado

El Análisis de Aptitud del Hábitat compara los servicios ecológicos proporcionados por los hábitat mencionados anteriormente con el arrecife eolianita según cuatro grupos funcionales: 1) productores primarios, 2) animales estructurales, 3) herbívoros (invertebrados y vertebrados), y 4) predadores (invertebrados y vertebrados). Los hábitat biogénicos y de fondo duro proporcionan un rango de funciones ecológicas a ambientes cercanos a la costa. La complejidad estructural característica de los hábitat de fondo duro proporciona un área donde se pueden adherir los productores primarios (e.g., algas y hierbas marinas) que a su vez proporcionan estructura y alimentos para una variedad de animales herbívoros (Heck et al., 2003). La adición de productores primarios de la comunidad de algas o aquellos característicos del hábitat creado (e.g. hierbas marinas y manglares) también sirve para procesar nutrientes inorgánicos y orgánicos. Si bien una fracción de estos nutrientes se asimilan en el tejido de las plantas, un gran porcentaje de esos nutrientes son trasferidos a niveles tróficos más elevados mediante el proceso de alimentación de los animales herbívoros. Además de la comunidad de productores primarios que se desarrolla en la estructura proporcionada por esos hábitat, los invertebrados sésiles (e.g., corales y esponjas) también colonizan el hábitat y proporcionan una estructura biogénica adicional. Las especies predadoras se sienten atraídas al refugio, proporcionado por el hábitat estructurado y/o el número aumentado de animales herbívoros, que pueden servir de presa. Luego entonces, se espera que la restauración compensatoria de los hábitat estructurados modifique al menos cuatro grupos funcionales (productores primarios, herbívoros, animales estructurales y predadores) y esos cuatro niveles sirven de base para nuestra comparación entre funciones.

Un diagrama esquemático para el enfoque utilizado durante el Análisis de Aptitud del Hábitat se presenta en la Figura 2. Se utilizó una investigación y compilación de bibliografía disponible concerniente a las comunidades de la flora y la fauna asociadas con el hábitat eolianita y los cuatro hábitat compensatorios potenciales para identificar las funciones ecológicas. Después que se completó el análisis de bibliografía, se compilaron listas de especies documentadas para cada hábitat. Esas especies documentadas se asignaron entonces a uno de los cuatro servicios ecológicos. Aunque reconocemos que una especie puede traslaparse con respecto a categorías de funciones (e.g., una especie de alga es un productor primario que también proporciona estructura), las asignamos a una categoría. En la lista de especies documentadas se incluyó información disponible sobre la etapa vital-histórica (i.e., juvenil, adulto y desovador). La nueva recopilación de datos o el análisis renovado de bases de datos previamente recopiladas rebasan el ámbito de este contrato; por ello el nivel de evaluación (cuantitativa y cualitativa) estuvo basado en la naturaleza de la información específicamente relacionada con el sitio encontrada en la bibliografía publicada. Se anticipó que habría una mayor disponibilidad de datos cuantitativos para evaluar la abundancia relativa de especies en las comparaciones de hábitat seleccionadas (Figura 2). Desafortunadamente, este nivel de análisis no se pudo realizar con la disponibilidad limitada de datos cuantitativos. En consecuencia, el Análisis de Aptitud del Hábitat que

presentamos aquí está basado en gran medida en los análisis de similitud entre el hábitat de arrecife eolianita y los cuatro hábitat compensatorios potenciales.

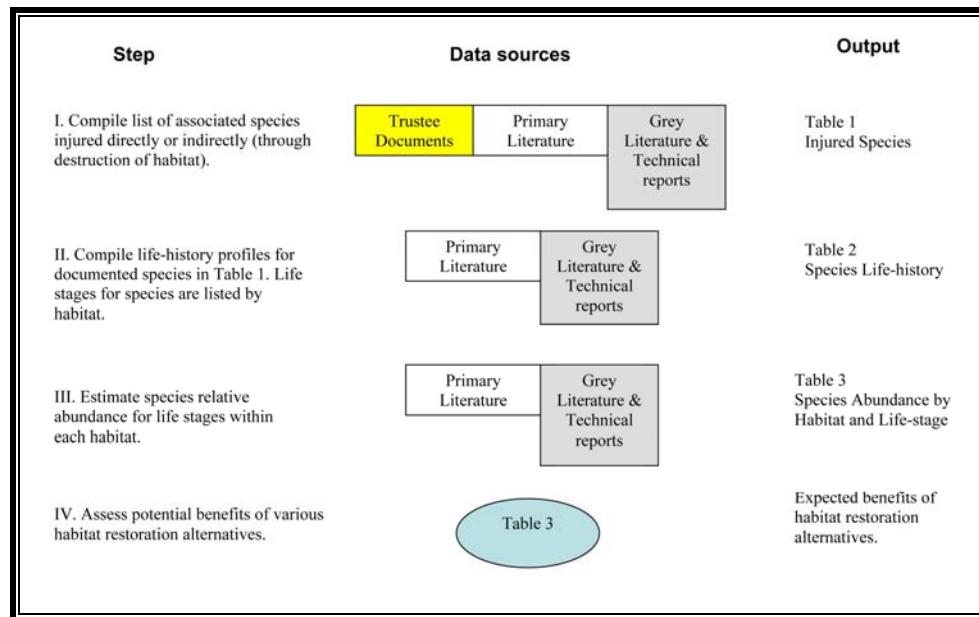


Figura 2. Diagrama esquemático para el enfoque utilizado durante el Análisis de Aptitud del Hábitat.

2.1 Investigación bibliográfica

Las fuentes bibliográficas son: 1) bibliografía primaria que incluyó artículos de revistas evaluados, tesis de grado de Maestría y dissertaciones de doctorado (PhD) y 2) bibliografía "gris" que incluyó documentos técnicos relacionados directamente con la encalladura del Morris J. Berman y que fueron provistos por los Fiduciarios, informes técnicos y búsquedas en Internet. La información pertinente a la flora y la fauna potencialmente dañadas ya sea directa o indirectamente por la encalladura del Morris J. Berman fue encontrada realizando una amplia investigación bibliográfica utilizando una lista de palabras clave. Se obtuvieron publicaciones gubernamentales adicionales mediante investigación del archivo documental de la NOAA ubicado en la Rosentiel School of Marine and Atmospheric Science en Miami Florida. Además, se utilizaron comunicaciones personales mediante teléfono y correo electrónico con vistas a recopilar información pertinente. El Apéndice A incluye una lista de las Fuentes bibliográficas evaluadas.

Las bases de datos en Internet utilizadas para la búsqueda bibliográfica incluyeron: 1) Science Direct (SD), 2) Academic Search Premier (EBSCO), 3) Cambridge Scientific Abstracts (CSA), 4) ProQuest Digital Dissertations (PDD), y 5) ISI Web of Knowledge (ISI). SD es la base de datos electrónica más extensa del mundo en lo que respecta a la información científica, técnica, bibliográfica y médica. EBESCO es una base de datos de interés general con más de 3.000 revistas indexadas que cubren una amplia variedad de tópicos, entre los que se encuentran las

ciencias sociales, empresas, humanidades, ciencia en general y educación. CSA proporciona acceso a más de 100 bases de datos temáticos publicados por CSA y sus socios editoriales. PDD contiene más de 1,6 millones de tesis y disertaciones, citas y resúmenes. ISB es una página web para búsqueda de palabras clave que permite acceder a varias revistas científicas evaluadas.

2.2 Análisis de Aptitud del Hábitat

Utilizando datos obtenidos de la revisión bibliográfica, se compiló una lista regional de especies comunes a la costa norte de Puerto Rico. Las especies en la lista regional que, según se pudo documentar, utilizan el hábitat del arrecife eolianita se identificaron a partir de documentos de evaluación de los daños provistos por los Fiduciarios y estudios de evaluación del hábitat realizados en hábitat similares de las cercanías. Las especies identificadas como utilizadoras del hábitat del arrecife eolianita se consideraron especies dañadas ya sea directa o indirectamente por el incidente de la encalladura. La utilización de los cuatro hábitat compensatorios potenciales por parte de las especies del arrecife eolianita se determinó entonces a partir de la investigación bibliográfica. Como paso próximo las especies se asignaron a una de cuatro categorías de funciones para su análisis (i.e. productores primarios, animales estructurales, herbívoros y predadores). Los predadores de zooplancton pelágico que son predominantemente pelágicos por naturaleza y carecen de una fuerte afinidad para los hábitat béníticos se situaron en una categoría separada (planctívora) y se excluyeron del análisis de predadores, de conformidad con Análisis de Aptitud del Hábitat anteriores que incluían la restauración de hábitat béníticos (Peterson et al. 2003). El Apéndice B incluye una lista regional de las especies detectadas costa afuera en la costa norte de Puerto Rico, con su categoría de función asociada, descriptor biológico y presencia/ausencia por hábitat.

Se creó una matriz de datos de las especies cuya presencia se documentó en el hábitat de arrecife eolianita, basada en una lista de especies regionales de la costa norte de Puerto Rico. Esta matriz de datos de especies de arrecife eolianita y su presencia/ausencia en el hábitat compensatorio sirvió de base para el análisis de similitud entre el hábitat de arrecife eolianita y los cuatro hábitat compensatorios posibles. En consecuencia, nuestro análisis de similitud está basado solamente en esas 183 especies presentes en el arrecife eolianita. El ordenamiento de los datos de similitud entre los tipos de hábitat (i.e. arrecife eolianita, fondo duro poco profundo, fondo duro profundo, hierbas marinas y manglares) se realizó utilizando escalamiento multidimensional no-métrico (nMDS) con el programa PRIMER 6 (Clarke y Warwick 2001). Un ordenamiento es un mapa de las muestras (i.e. hábitat), usualmente en dos o tres dimensiones, en el cual la ubicación de las muestras (i.e. hábitat) refleja la similitud de sus comunidades biológicas. Los puntos cercanos tienen una comunidad biológica muy similar, mientras que los puntos más distantes tienen comunidades disímiles. El primer paso en el método nMDS es construir una matriz de similitud entre las muestras (hábitat). La matriz de similitud se basó en las distancias de similitud de Braz-Curtis, método utilizado ampliamente para calcular la similitud entre muestras utilizando datos de presencia/ausencia para las especies marinas detectadas en el hábitat de arrecife eolianita situado en las afueras de la costa norte de Puerto Rico. Las distancias de Braz Curtis expresan el grado de similitud de dos hábitat, basándose en una escala de 0-100, indicando el valor de 100 la similitud más elevada. El método nMDS utiliza entonces los rangos de las similitudes entre los 5 tipos de hábitat (no las medidas de distancia reales) para construir la parcela de ordenamiento. NMDS utiliza los rangos relativos en la visualización de parcelas, por lo que los ejes no tienen

unidades especificadas. Se realizaron cuatro análisis nMDS separados, uno por cada función ecológica (i.e. productores primarios, animales estructurales, herbívoros y predadores). Se utilizaron comparaciones visuales de parcelas generadas por cada servicio ecológico para caracterizar diferencias en la estructura comunitaria entre los cinco tipos de hábitat. En la Sección 3.4 se presentan y describen las parcelas.

Se realizó una evaluación cualitativa adicional del hábitat de arrecife de eolianita y los cuatro hábitat compensatorios posibles mediante un resumen de la información relativa a la historia vital (cuando estuvo disponible) de los organismos que fueron dañados directa o indirectamente por la degradación/pérdida del hábitat (Apéndice B). Estos datos, sobre todo centrándose el interés en especies predadoras, proporcionarán la base para una evaluación limitada de la utilización del hábitat por etapa de historia vital (i.e. juvenil, adulto y desovador). No se llevó a cabo ningún análisis formal por etapa de historia vital debido a lo limitado de los datos; los datos de historia vital se utilizarán como factores cualitativos en la discusión de beneficios potenciales a la comunidad predadora.

3.0 RESULTADOS

3.1 Sinopsis de investigación bibliográfica

Los informes de evolución de daños y otros documentos relacionados con la encalladura del Morris J. Berman los proporcionaron y revisaron los Fiduciarios antes que se hiciera la investigación bibliográfica. Documentos relativos a la encalladura y evaluaciones de hábitat similares se utilizaron para crear una lista de especies presentes en el hábitat del arrecife eolianita y para describir el arrecife (el recurso) dañado. La lista de especies, descripción del sitio y las descripciones del hábitat compensatorio potencial se utilizaron para crear una lista de palabras clave que fue utilizada en la investigación bibliográfica. Los resultados de la investigación bibliográfica y de las bases de datos de Internet obtenidos mediante el uso de palabras clave aparecen en la Tabla 1. La investigación bibliográfica inicialmente se centró primordialmente en bibliografía pertinente sobre hábitat marinos de Puerto Rico, pero se expandió posteriormente hasta incluir el Caribe y el sur de la Florida debido a falta de información sobre la costa norte de Puerto Rico. Se recopilaron y examinaron un total de 362 referencias durante el programa de Análisis de Aptitud del Hábitat (Tabla 1).

Las referencias recopiladas durante la búsqueda bibliográfica se asignaron a categorías temáticas generales y grupos funcionales dentro de una categoría. El número de referencias para cada grupo funcional dentro de las categorías se presenta en la Tabla 2. La mayoría de las referencias proporcionarán información sobre la historia vital y la biología básica de las especies potencialmente presentes en Puerto Rico. Si bien un número relativamente amplio de estudios específicamente relacionados con sitios concernientes a las historias vitales y/o investigación sobre el campo ecológico fueron identificados como relativos a Puerto Rico, la mayoría de estos estudios se realizó en hábitat de arrecifes coralinos a lo largo de la costa suroccidental y no eran aplicables al hábitat de arrecife eolianita dañado durante la encalladura (Lisa Caramba, 2005, comunicación personal, Puerto Rico National Marine Fisheries Service). Los pocos estudios realizados en áreas cercanas al sitio donde encalló la embarcación eran primariamente estudios cualitativos que reportaban solamente información sobre presencia/ausencia. De modo similar, se encontraron pocos estudios sobre hábitat de manglares y hierbas marinas relativos a la costa norte de Puerto Rico.

Tabla 1. Las palabras clave y las bases de datos utilizados para el Análisis de Aptitud del Hábitat (HSA). Las fuentes potenciales y la bibliografía sobre HSA selecta (en paréntesis) se presentan para cada base de datos. Los guiones indican que no se ha efectuado búsqueda para la palabra clave de que se trate.

Palabras clave			Base de datos				
			SD	EBSCO	CSA	PDD	ISI
Puerto Rico			620	4,732	195(6)	--	2,465
Puerto Rico	&	Industria pesquera	2(0)	9(1)	2(0)	6(3)	10(1)
	&	Arrecife	19(3)	20(10)	4(0)	22(13)	78(20)
	&	Hierba marina	7(1)	2(0)	2(0)	10(6)	18(5)
	&	Manglares	11(3)	9(1)	1(0)	1(1)	25(8)
	&	Hábitat cercano a la costa	2(1)	0	0	0	1(1)
	&	Producción de peces	0	1(0)	1(0)	--	0
	&	Peces	17(3)	4(4)	8(2)	32(9)	90(17)
	&	Ictiofauna	0	0	0	--	0
	&	Tortugas	1(1)	1(1)	1(0)	--	6(1)
	&	Béntico	8(0)	12(2)	2(0)	8(3)	38(3)
	&	Caballito de mar	0	0	0	--	0
	&	Hábitat de fondo duro	0	0	0	0	2(0)
Caribe	&	Industria pesquera	38(2)	74(13)	14(2)	18(1)	94(4)
	&	Arrecifes	154(10)	234(27)	20(10)	101(9)	897(35)
	&	Hierba marina	38(7)	15(8)	18(0)	18(7)	124(11)
	&	Manglares	34(4)	44(8)	82(8)	18	153(19)
	&	Hábitat cercano a la costa	1(1)	1(1)	0	--	1(0)
	&	Producción de peces	7(1)	0	0	--	0
	&	Peces	103(11)	125(0)	689(25)	62(10)	448(18)
	&	Ictiofauna	0	0	0	--	0
	&	Tortugas marinas	1(1)	31(2)	39(1)	--	22(0)
	&	Béntico	45(0)	31(2)	216(9)	31(5)	222(5)
	&	Hábitat de fondo duro	2(0)	0	1(0)	1(0)	5(0)
	&	Erizo de fondo	13(6)	2(0)	0	6(2)	46(3)
	&	Hábitat	84(8)	118(23)	12(0)	--	347(21)
Ciclo vital	&	Corales	42(5)	10(1)	82(3)	--	94(4)
	&	Esponjas	12(0)	1(0)	25(0)	--	27(0)
	&	Erizos de fondo	9(0)	7(0)	25(0)	--	69(0)
Reproducción	&	Corales	0	40(1)	124(3)	--	239(3)
	&	Esponjas	0	50(0)	81(2)	--	111(0)
Índice de	&	Corales	207(8)	37(1)	134(3)	--	195(2)

Tabla 2. Se relaciona el número de referencias para cada grupo funcional dentro de las categorías temáticas. Una referencia puede aparecer en más de una categoría.

Categoría	Grupo	Total
Ciclo vital		
	Algas	6
	Invertebrados sésiles	30
	Invertebrados móviles	35
	Tortugas	7
	Peces/tiburones	88
Específicos del sitio		
	Puerto Rico (P.R.)	71
	Sitio de la encalladura	12
	P.R. Costa Norte	9
Hábitat general		
	Hierba marina	24
	Arrecife poco profundo: 5-10 m	17
	Arrecife profundo: >10 m	5
	Manglares	38
Conceptual		45
Otros		14

3.2 Caracterización del sitio donde encalló el Morris J. Berman

Puerto Rico, situado al borde de la plataforma caribeña, tiene una compleja línea costera al norte del país, integrada predominantemente por formaciones de piedra caliza y llanuras de aluvión que contribuyeron a la formación de playas y dunas. (Krushansky y Schellekens 2001). La plataforma insular a lo largo de la costa norte, tiene menos de 1 milla de ancho y experimenta intensas marejadas y corrientes a todo lo largo de la costa (Glauco A. Rivera & Associates, 2003). La altura de las olas a lo largo de la costa norte de Puerto Rico, generadas predominantemente por los vientos alisios, alcanzan entre 1 y 3 m (Morelock, 1978). Estas condiciones físicas, en conjunción con una erosión desproporcionada del substrato de piedra caliza, crean formaciones coralinas de localización topográfica variable. Rocas de playa litificadas y dunas de arena fosilizada (i.e. eolianitas) son características de las zonas cercanas a la costa, típicas del área de San Juan. Los arrecifes eolianitas son estructuras de fondo duro sumergidas, compuestas de depósitos de arena cementados conjuntamente con carbonato de calcio. A lo largo de la costa norte de Puerto Rico, esos arrecifes están orientados de oeste a noroeste, siguiendo una ruta ligeramente sinuosa (Kaye, 1959).

La barcaza Morris J. Berman chocó contra el lado que da al mar de un arrecife eolianita de alta energía en profundidades entre 2,4 y 4,6 m (8 a 15 pies) que sigue un curso paralelo a la línea costera. El arrecife eolianita dañado, fuertemente influenciado por una alta energía de olas y

grandes influjos de sedimentos de río, fue caracterizado por Hudson y Goodwin (1995) como estructuralmente complejo debido a procesos erosionales de la tierra y el mar que han creado una microtopografía de pequeños fosos, huecos y grietas dentro del afloramientos de rocas, cavidades poco profundas y zanjas resistentes a la erosión y distribuidos al azar. El hábitat de arrecife eolianita dañado no muestra ninguna evidencia de adición de arrecife de coral a largo plazo o depósitos de arrecifes coralinos relictos.

El hábitat dañado por la encalladura del Morris J. Berman forma parte de un arrecife continuo de una zona cercana a la costa que se extiende a lo largo de la costa de San Juan según se muestra en la Figura 1 (Kendall et al., 2001). A continuación de la encalladura, Vicente (1994), Entrix (1995) y Hudson, y Goodwin (1995) caracterizaron los nuevos recursos biológicos del hábitat de arrecife eolianita dañado así como áreas de referencia no dañadas. Estos documentos proporcionaron información cualitativa tal como listas de especies en hábitat eolianitas no dañados y descripciones de hábitat en general. Otros estudios proporcionando descripciones cualitativas y descripciones cuantitativas limitadas del hábitat de arrecife eolianita a lo largo de la costa norte incluyeron caracterizaciones del corredor del oleoducto en aguas costa afuera de Isla Verde, Puerto Rico, realizadas por Vicente & Associates (2000) y Glauco A. Rivera & Associates (2003). Dial Cordy & Associates (2000) realizó una evaluación de un hábitat similar costa afuera de Arecibo, Puerto Rico, aproximadamente 60 km al oeste del sitio donde encalló la embarcación. CSA Architects and Engineers et al. (2004) realizaron una evaluación de hábitat para la Autoridad de Acueductos y Alcantarillados de Puerto Rico (Puerto Rico Aqueducts and Sewer Authority (PAASA)) en hábitat de fondo duro similares al este de Puerto Rico, que proporcionó datos cuantitativos limitados sobre la comunidad de peces y corales. Mignucci-Giannoni (1999) identificó más de 152 especies y 15 grupos taxonómicos de organismos marinos afectados por el derrame de petróleo del Morris J. Berman, según fue documentado a partir de especímenes recogidos a lo largo de la costa después del incidente por la Caribbean Stranding Network. Mignucci-Giannoni (1999) estableció que la flora y la fauna más comúnmente afectada a consecuencia de la encalladura y el subsecuente derrame de petróleo eran equinodermos, moluscos y crustáceos, que constituyan el 58, 25 y 10 por ciento respectivamente. Los vertebrados, primariamente peces, constituyan aproximadamente el 6% de los organismos marinos afectados por la encalladura del Morris J. Berman (Mignucci-Giannoni, 1999). El arrecife eolianita dañado por el Morris J. Berman estaba visualmente dominado por corales blandos, esponjas y macroalgas.

3.3 Composición de las especies del hábitat del arrecife

Una lista completa de las especies cuya presencia se ha registrado aguas fuera de la costa norte de Puerto Rico con categoría de función, descriptor biológico y presencia/ausencia asociados por hábitat fue compilada mediante una revisión de la bibliografía recopilada y se presenta como Apéndice B. La etapa de historia vital (juvenil, adulto y desovador) se presenta respecto de algunas de las especies documentadas; los datos sobre historia vital no estaban disponibles para la mayoría de las especies. De las 478 especies marinas documentadas a lo largo de la costa norte de Puerto Rico se documentó la presencia de 183 dentro del hábitat de arrecife eolianita. Los grupos de la fauna con la mayor cantidad de especies directa o indirectamente afectadas por la pérdida de hábitat debido a la encalladura de la embarcación fueron los peces, esponjas y corales (duros y blandos) con porcentajes de 108, 24 y 25 respectivamente (Apéndice B).

3.3.1 Productores primarios

Los productores primarios son organismos, más a menudo plantas, que convierten el dióxido de carbono en energía química mediante la fotosíntesis. Los productores primarios son importantes componentes de la comunidad de arrecifes porque proporcionan alimento y estructura a niveles tróficos superiores. Las algas son los macrobentos más diversos a lo largo de la costa norte de Puerto Rico e incluyeron 113 especies de algas rojas, 59 especies de algas verdes y 33 especies de algas carmelitas (Apéndice B).

Se documentó la presencia de catorce especies de algas en el hábitat del arrecife eolianita (Apéndice B). Conjuntos mixtos de algas coralinas articuladas rojas, algas rojas, verdes y carmelitas son visualmente dominantes en el área del sitio donde encalló la embarcación (Vicente & Associates, 2000). Algas verdes y carmelitas tales como la *Halimeda discoidea*, la *Udotea flabellum* y la *Dictyota spp.* son productos primarios importantes que forman terrones sueltos o colchones densos sobre substratos rocosos poco profundos. Las *Halimeda spp.*, algas calcáreas verdes, son también una fuente importante de sedimentos de arrecife. Las algas coralinas son beneficiosas a los hábitat de arrecifes ya que unen los substratos de arrecife y aumentan la integridad estructural del hábitat. La consolidación del substrato de arrecife por las algas coralinas crea microhábitat para varios invertebrados tales como *Comosea urchius*, Mollusca polyplacophora (quitones) y lapas juveniles. Las algas rojas carnosas, tales como la *Bryothamnion triquetum*, *Gracilaria dominguensis* y *Amansia multifida* son espesas y proporcionan hábitat estructuralmente complejos para muchos peces e invertebrados pequeños. Las listas de control regionales de algas béticas se han compilado por Almodóvar y Ballantine (1983); Ballantine y Norris (1989); Ballantine y Aponte (1997); y Ballantine et al. (2004).

3.3.2 Animales estructurales

Los animales estructurales son organismos sésiles que se adhieren al substrato y subsecuentemente aumentan su complejidad estructural. Si bien muchas especies de plantas y algas aumentan la complejidad estructural de su ambiente según se discutió anteriormente, su función primaria en su medio es proporcionar alimento para niveles tróficos superiores y por lo tanto fueron descritos y analizados como productores primarios. Los organismos más comunes documentados a lo largo de la costa norte de Puerto Rico que aumentan la complejidad estructural del ambiente en el que habitan son corales blandos y duros, así como esponjas.

Los corales suaves son un componente conspicuo de las comunidades marinas de todo el mundo. Los corales blandos tienen morfologías de ramificación o de abanico que ayudan a que haya una mínima explotación de los substratos duros mientras que se utiliza un gran volumen de la columna de agua (Barnes 1980). Los corales blandos, en virtud de sus morfos coloniales arborescentes comunes, proporcionan complejidad estructural y alivio vertical al hábitat físico. Los corales blandos proporcionan refugio a varias plantas simbióticas y epizoicas y animales que o bien se adhieren a la superficie o se arrastran por ella. Algunos de los simbiontes adoptan el color de los corales blandos que les sirven de anfitrión (Barnes 1980). Los corales suaves comunes presentes a lo largo de la costa norte de Puerto Rico incluyen las gorgónneas (*Gorgonia sp*), los *Pterogorgia citrina* (yellow sea whips) y los *Eunnicea spp* (sea rods) (Vicente &

Associates 2000). Se documentó la presencia en el hábitat de arrecife eolianita de trece de las quince especies de coral blando presentes a lo largo de la costa norte (Apéndice B).

Los corales escleractinianos, o corales duros, son los más importantes de los organismos que generan carbonato de calcio y son el mayor contribuyente estructural a la formación de corales moderna. La morfología de la colonia de corales duros es variable y está dictada primariamente por especies y factores ambientales. Por ejemplo, las morfologías de colonias de bajo perfil, a menudo denominadas formas de placas incrustadas, son más indicativas de ambientes de alta energía. Los corales duros proporcionan complejidad estructural y un área de superficie aumentada y abundancia de macroinvertebrados sésiles, los cuales influencian la diversidad y abundancia de peces (Ferreira et al. 2001). Los corales duros proporcionan al hábitat una forma tridimensional en cuanto al relieve vertical y los intersticios, todo lo cual ejerce influencia en el número de especies de peces presentes en los arrecifes y en su abundancia (Luckhurst y Luckhurst 1978; Dennis y Bright 1998). Algunas de las especies comunes de corales duros encontradas colonizando el substrato de fondo duro poco profundo a lo largo de la costa norte de Puerto Rico son el *Montastrea cavernosa* (great star coral), *Diplora stugosa* (coral de cerebro simétrico), y el coral masivo estrellado (*Siderastrea siderea*), el *Porites astreoides* (mustard hill coral) y *P. porites* (finger coral). De las veinte y cuatro especies de corales duros documentados a lo largo de la costa norte de Puerto Rico, se documentó la presencia de 12 especies en el hábitat del arrecife eolianita y fueron por ello potencialmente directamente dañados por la encalladura del Merris J. Berman (Apéndice B).

La vasta mayoría de las esponjas son organismos que filtran los alimentos y constituyen una importante componente de la comunidad de fondo duro. Las esponjas son altamente diversas en lo concerniente a sus funciones ecológicas; en particular se ha documentado que las especies de aguas poco profundas promueven la consolidación de escombros de substrato (Wulff 1984), contribuyen a la bioerosión de los substratos duros y modifican la morfología de coral duro (Gorean y Hartman 1966). Al menos se ha documentado la presencia de 24 diferentes especies de esponjas a lo largo de la costa de Puerto Rico, reportándose que diez y nueve de ellas habitaban el arrecife eolianita (Apéndice B). Las esponjas observadas comúnmente en el arrecife eolianita incluyen la *Xestopongia muta* (giant barrel sponge), la *Anthosigmella varians* (brown variable sponge) y el *Callyspongia vaginalis* (vase sponge). La *X. muta*, esponja voluminosa de gran anchura y que puede alcanzar una altura de un metro, proporciona mayor complejidad estructural en el arrecife y en el hábitat para numerosas esponjas inquilinas tales como la estrella crispada (brittle stars) y el *Alpheus normanni* (snapping shrimp). La especie *A. varians* tiene dos formas de crecimiento distintivas que incluyen una forma de lobato amorfa y una forma de incrustación expansiva. La *C. vaginalis* es una esponja relativamente grande y con derivaciones que proporciona hábitat para el *Parsazoanthus sp.* (zoántidos) y otros invertebrados.

3.3.3 Herbívoros

Los herbívoros son animales que consumen productores primarios como fuente de energía. Ambos invertebrados, tales como el erizo de fondo y vertebrados como peces y tortugas marinas, se pueden caracterizar como herbívoros si su dieta consiste primariamente en productores primarios. Dentro de las comunidades de arrecifes los herbívoros proporcionan alimentos para organismos predadores y ayudan a mantener un equilibrio entre los productores primarios y los

animales estructurales. Quince especies de herbívoros vertebrados y seis especies de herbívoros invertebrados están presentes en el hábitat de arrecife eolianita y se vieron potencialmente dañados por el encallamiento de la embarcación.

3.3.3.1 Invertebrados

Entre los invertebrados marinos motiles dañados por la encalladura del Morris J. Berman se encuentran varios crustáceos equinodermos equinoides y un molusco gastrópodo. Los equinodermos equinoides (i.e. erizo de fondo) son un componente importante del sistema de arrecife que ayuda a mantener la disponibilidad del substrato y la complejidad estructural del hábitat. El erizo de la especie *Echinometra lucunter* es un bioerosionador que descompone el substrato y ayuda a mantener los microhábitat altamente variables dentro de la estructura del arrecife. La creación del hábitat dentro de la estructura facilita la diversidad de especies debido a la partición del nicho y a la zonación de la flora y la fauna. Los erizos herbívoros, tales como el *Diadema antillarum*, el erizo multicolor (*Lytechinus variegatus*) y el *Tripneustes ventricosus* (erizo de fondo blanco), que se alimentan de algas, facilitan la progresión sucesional proporcionando substrato disponible para las especies de arrecife. Se reportó una disminución de la población de erizos de fondo a sólo unos días de la encalladura del Morris J. Berman; los erizos que fueron encontrados vivos mostraban señales de haber sido afectados por el petróleo tales como pérdida de espinas dorsales, pobre adherencia al substrato y penachos de algas creciendo en las espinas dorsales (Vicente, 1994). La concha Reina del Caribe (*Strombus gigas*) es un molusco herbívoro común en lechos de hierbas marinas y lechos de algas cuya presencia se documentó en los informes de evaluación de los daños como afectados por la encalladura del Morris J. Berman. La concha Reina del Caribe es una importante especie comercial de Puerto Rico y aparece listada en el Apéndice II de la Convención de Comercio Internacional en Especies de Extinción (CITES) como especie amenazada.

3.3.3.2 Vertebrados

El hábitat de fondo duro de la costa norte se considera un hábitat de preocupación para la especie amenazada *Chelonia mydas* (tortuga) y la *Eretmochelys imbricata* (tortuga carey). Durante los esfuerzos de rescate y rehabilitación que siguieron a la encalladura, dos tortugas embadurnadas de petróleo fueron tratadas por la entidad Caribbean Stranding Network (Mignucci-Giannoni 1999). Las tortugas, con un suave carapacho negro, carmelita, verde y gris, pueden alcanzar hasta 4 pies de longitud y llegar a pesar hasta 500 libras. Las tortugas adultas son herbívoras y comen primariamente hierbas marinas y algas. Las tortugas juveniles son carnívoras que consumen medusas y otros invertebrados encontrados en el hábitat de arrecife eolianita. La *Eretmochelys imbricata* (tortuga carey) es una tortuga de pequeño a mediano tamaño, aproximadamente de 2 a 3 pies de largo y con un peso de 180 libras. Las tortugas se alimentan primariamente de esponjas presentes en los hábitat de fondos duros. Se sabe que los especímenes juveniles se alimentan de algas en áreas costeras de fondo duro del norte de Puerto Rico.

Los peces herbívoros dentro del hábitat eolianita incluyen 8 familias de ictiofauna (Apéndice B). Estos herbívoros se alimentan exclusivamente ya sea de algas que crecen directamente en el arrecife o de plancton en la columna de agua por encima del arrecife. Los acantúridos (pez cirujano, 3 especies), pomacéntridos (damisela coliamarilla o *Microspathodon chrysurus*, 2

especies), escáridos (loro boquiazul, 5 especies), los blénidos (blenio boquicolorado, *Ophioblennius atlanticus*) y un Monacanthid (lijas naranja o pereza, *Aluterus punctatus*) son peces herbívoros que se alimentan de algas incrustadas y se encuentran en el hábitat de arrecife eolianita. Los herbívoros asociados a los arrecifes de plancton incluyen una especie de anchoveta, (la *Cetengraulis edentulus*), Exocoetids (peces voladores, 2 especies) y un pomacéntrido (burrito o cromis, *Chromis cyaneus*)

3.3.4 Predadores

Los predadores son animales que se alimentan de otros animales. Ambos invertebrados, tales como la langosta espinosa (*Panulirus argus*) y los vertebrados, tales como el pargo (*Epinephelus morio*), se alimentan de herbívoros y otros pequeños animales predadores (Apéndice B). Las actividades predadoras afectan el reclutamiento de peces e invertebrados juveniles para las comunidades de arrecifes (Hixon, 1991) e influencian los conjuntos de arrecifes mediante el control de las poblaciones de herbívoros que podrían sobrealmacenarse de los conjuntos de plantas. En total, se ha documentado en los arrecifes eolianitas de la costa norte de Puerto Rico la existencia de 57 familias que agrupan 98 especies de ictiofauna predadora y 2 especies de invertebrados.

3.3.4.1 Invertebrados

La langosta espinosa (*P. argus*) y los *Callinectes spp.* (cangrejos azules) son importantes especies comerciales de crustáceos que probablemente experimentaron daños indirectos debido a la pérdida de hábitat como resultado de la encalladura.

3.3.4.2 Vertebrados

Entre la ictiofauna cuya existencia se ha documentado en los arrecifes eolianitas a lo largo de la costa norte de Puerto Rico se encuentran predadores de alto calibre, especies asociadas a los demersales y especies pelágicas (Apéndice B). El *Carcharhinus leucas* (sarda), el *Carchaninus limbatus* (coconeta punta prieta), la barracuda (*Sphyraena barracuda*), el *Megalops atlanticus* (tarpón o sábalo) y cuatro especies de róbalo (e.g., *Centropomus unidecimalis*) son todos predadores de calibre presentes en el hábitat de arrecife eolianita. Se ha documentado la existencia en el hábitat de arrecifes eolianitas de la costa norte de Puerto Rico de veinte y dos especies predadoras del grupo de chernas asociadas con los demersales [i.e. *Epinephelus morio* (mero guasa), *Haemulon album* (margate), *Calamus bajonado* (bajonado) y el *Lachnolaimus maximus* (peje perro)]. Tres especies predadoras pelágicas tales como al *Caranx ruber* (cojinúa blanca o chibí), el *Chloroscombus crysurus* (casave o bagre) y el chicharro o cobeo (*Selar crumenophthalmus*) se alimentan del hábitat de aguas abiertas y adyacente al hábitat de arrecife eolianita.

3.4 Análisis de Aptitud del Hábitat

El Análisis de Aptitud del Hábitat compara las funciones ecológicas provistas por los hábitat mencionados anteriormente con el hábitat de arrecife eolianita respecto de cuatro grupos funcionales: 1) productores primarios, 2) animales estructurales, 3) herbívoros (invertebrados y vertebrados). Debido a que la mayoría de los estudios realizados en áreas cercanas a la encalladura y dentro de los cuatro hábitat compensatorios posibles eran primariamente cualitativos, nuestros análisis se restringieron a la comparación de datos de presencia/ausencia. El escalamiento multidimensional no métrico (nMDS), un tipo de ordenamiento que generó parcelas de similitud relativa de los cinco tipos de hábitat (los puntos más cercanos entre sí tienen mayor similitud) se utilizaron como la base para el Análisis de Aptitud del Hábitat. El escalamiento multidimensional no métrico utiliza rangos relativos en la visualización de las parcelas, los ejes no tienen unidades específicas. Las distancias de Bray-Curtis, que se utilizaron para determinar los rangos de relativa similitud, se presentan también para proporcionar un índice más numérico de similitud.

3.4.1 Productores primarios

En la base de la cadena alimentaria del hábitat de arrecife eolianita, así como en los cuatro posibles hábitat de compensación, se encuentran productores primarios (algas, hierbas marinas y manglares) que proporcionan dos importantes funciones ecológicas: alimento para herbívoros y complejidad estructural para pequeños invertebrados y peces juveniles. La presencia/ausencia de 14 especies de algas verdes, rojas y carmelitas se utilizó como la base para construir una matriz de similitud. El fondo duro de aguas poco profundas demostraron el más alto grado de similitud con respecto del arrecife eolianita (Figura 3). El mangle, un hábitat que sirve de sustento a un alto nivel de producción primaria debido a su naturaleza biogénica, se clasificó en 2do lugar, seguido del fondo duro de aguas profundas y la hierba marina (Tabla 3).

Figura 3. Parcela de escalamiento multidimensional que ilustra la similitud de los cinco hábitat basándose en la presencia/ausencia de productores primarios de arrecifes eolianitas. La tensión indica el grado hasta el cual la parcela representa los datos. Los valores inferiores a 0,1 se consideran altamente representativos.

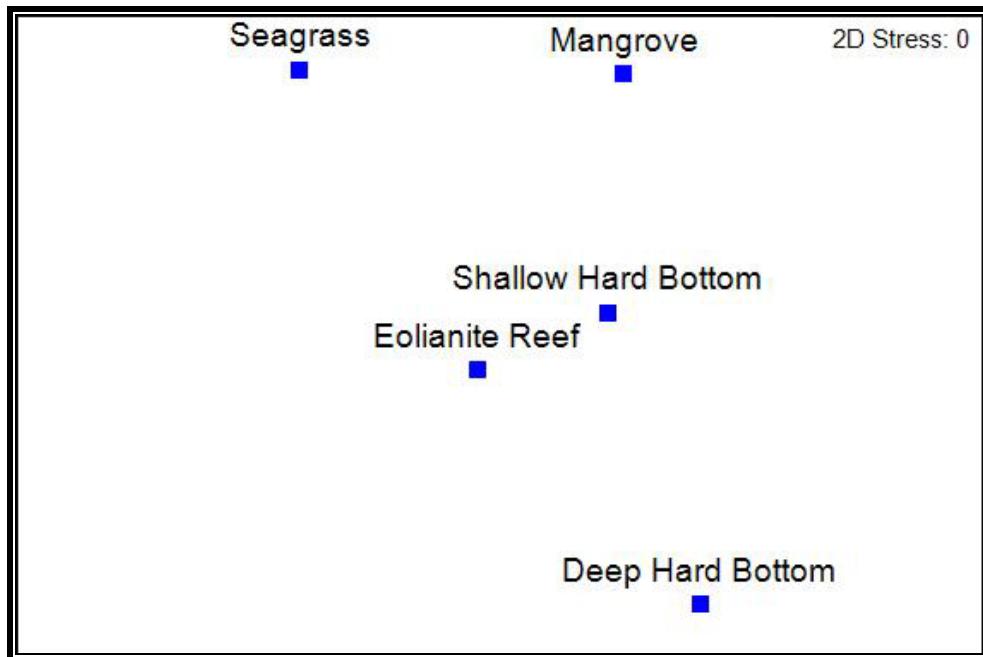


Tabla 3. Coeficientes de similitud de Bray-Curtis (0-100 con un valor de 100 indicando la mayor similitud) para los cinco hábitat, basado en la presencia/ausencia de productores primarios.

HÁBITATS	Arrecife eolianita	Fondo duro poco profundo	Fondo duro profundo	Hierba marina	Manglares
Arrecife eolianita					
Fondo duro poco profundo	66,7				
Fondo duro profundo	35,3	40,0			
Hierba marina	25,0	22,2	0		
Manglar	35,4	60,0	0	40,0	

3.4.2 Animales estructurales

Los corales y esponjas son especies comunes que se encuentran en el hábitat del arrecife eolianita y que son un elemento estructural fundamental para los peces e invertebrados (véase Sección 3.3.2). Basado en la presencia/ausencia de 53 especies (primariamente corales blandos, corales duros y esponjas), la mayor similitud de la fauna se encontró entre el hábitat de arrecife eolianita y el hábitat de fondo duro en aguas poco profundas (Figura 4; Tabla 5). El fondo duro en aguas profundas, que se clasificó en segundo lugar, y la hierba marina, que se clasificó en tercer lugar en similitud con respecto del arrecife eolianita, estuvieron cercanos en cuanto al nivel de similitud. Los manglares fueron los hábitat más disímiles con respecto del arrecife eolianita. Las diferencias entre los hábitat de arrecife eolianita, mangles y hierbas marinas en términos de animales estructurales se neutralizan, en cuanto a la provisión de refugio estructural para peces, mediante la estructura provista por la raíz expuesta del mangle o el área de hojas de la hierba marina.

Figura 4. La parcela de escalamiento multidimensional ilustra la similitud de los cinco hábitat basándose en la presencia/ausencia de los animales estructurales (primariamente corales blandos, corales duros y esponjas). La tensión indica el grado hasta el cual la parcela representa los datos. Los valores inferiores a 0,1 se consideran altamente representativos.

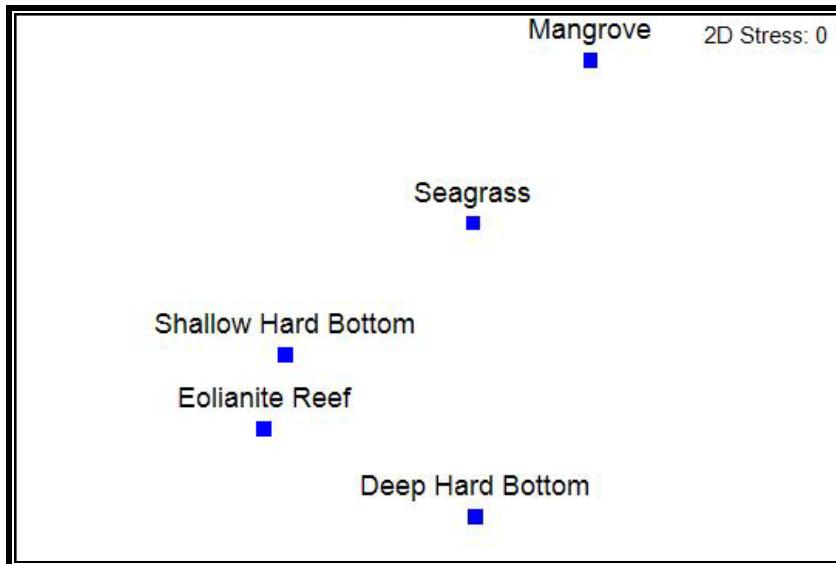


Tabla 5. Coeficientes de similitud de Bray-Curtis (0-100 con un valor de 100 indicando la mayor similitud) para los cinco hábitat, basado en la presencia/ausencia de productores primarios.

HÁBITATS	Arrecife eolianita	Fondo duro poco profundo	Fondo duro profundo	Hierba marina	Manglar
Arrecife eolianita					
Fondo duro poco	84,8				

profundo					
Fondo duro profundo	34,4	32,0			
Hierba marina	31,8	36,8	19,1		
Manglar	10,8	14,3	14,3	46,2	

3.4.3 Herbívoros

Se sabe que los hábitat costeros y cercanos a la costa, a lo largo de la costa de Puerto Rico, poseen una rica abundancia de peces e invertebrados herbívoros. Basado en nuestro análisis bibliográfico, 20 especies de peces herbívoros (e.g., pez cirujano, loro boquiazul, mújiles y salmonetes) e invertebrados (erizos de fondo, gastrópodos) con probabilidad se encontrarían en el hábitat de arrecife eolianita. Con la excepción del fondo duro de aguas profundas, la similitud fue alta entre los tipos de hábitat (Figura 5, Tabla 6). El alto grado de similitud entre los hábitat del arrecife eolianita, el fondo duro de aguas poco profundas y el de las hierbas marinas se debió en gran medida al traslapo de la comunidad de peces herbívoros y, en menor grado, a los equinodermos. En el fondo duro de aguas profundas se documentó poca presencia de especies herbívoras: dos especies de loros boquiazul y una de peces cirujanos (véase Apéndice B).

Figura 5. La parcela de escalamiento multidimensional ilustra la similitud de los cinco hábitat basándose en la presencia/ausencia de especies herbívoras (vertebrados e invertebrados). La tensión indica el grado hasta el cual la parcela representa los datos. Los valores inferiores a 0,1 se consideran altamente representativos.

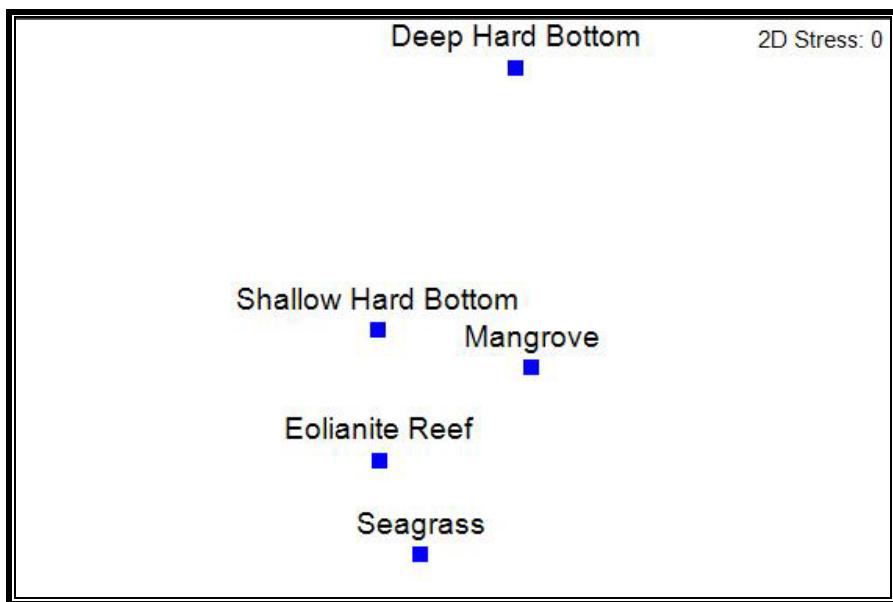


Tabla 6. Coeficientes de similitud de Bray-Curtis (0-100 con un valor de 100 indicando la mayor similitud) para los cinco hábitat, basado en la presencia/ausencia de herbívoros.

HÁBITATS	Arrecife eolianita	Fondo duro poco profundo	Fondo duro profundo	Hierba marina	Manglar
Arrecife eolianita					
Fondo duro poco profundo					
Fondo duro profundo	24,0	37,5			

Hierba marina	77,8	59,3	23,6		
Manglar	66,7	66,7	28,6	64,0	

3.4.4 Predadores

Los predadores representan un conjunto altamente diverso de peces e invertebrados que utilizan los cinco hábitat como refugio estructural y/o áreas de forraje. Se documentó la presencia de 94 predadores en el hábitat de arrecife eolianita. El hábitat de fondo duro en aguas poco profundas fue el más similar al hábitat de arrecife eolianita basado esto en la presencia de especies predadoras (Figura 6). En general, todos los cuatro hábitat compensatorios potenciales mostraron gran similitud (valores de Bray Curtis > 50, Tabla 7) con respecto del arrecife eolianita. El hábitat de fondo duro en aguas poco profundas fue el más similar, seguido del hábitat de hierbas marinas, mangle y el de fondo duro en aguas profundas (Tabla 7). Las especies de significado comercial o recreativo, en particular el pargo, el mero y los roncos (*Haemulon plumieri*), fueron comunes a todos los hábitat. Las langostas espinosas estuvieron presentes en todos los hábitat excepto en el de fondo duro en aguas profundas.

Figura 6. La parcela de escalamiento multidimensional ilustra la similitud de los cinco hábitat basándose en la presencia/ausencia de especies herbívoras (vertebrados e invertebrados). La tensión indica el grado hasta el cual la parcela representa los datos. Los valores inferiores a 0,1 se consideran altamente representativos.

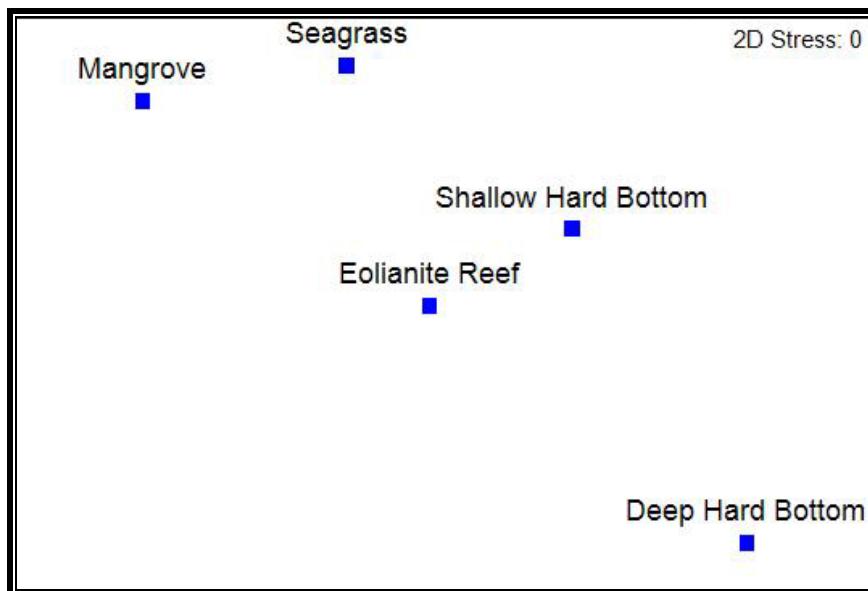


Tabla 7. Coeficientes de similitud de Bray-Curtis (0-100 con un valor de 100 indicando la mayor similitud) para los cinco hábitat, basado en la presencia/ausencia de predadores.

HÁBITATS	Arrecife eolianita	Fondo duro poco profundo	Fondo duro profundo	Hierba marina	Manglar
----------	--------------------	--------------------------	---------------------	---------------	---------

Arrecife eolianita					
Fondo duro poco profundo	81,0				
Fondo duro profundo	54,3	62,6			
Hierba marina	73,9	68,9	53,3		
Manglar	67,6	53,5	50,6	75,7	

Información detallada sobre la utilización del hábitat estuvo disponible para algunas especies importantes desde el punto de vista recreacional. Se reportó que dos especies de invertebrados objeto de explotación, la langosta espinosa (*P. argus*) y la concha Reina del Caribe (*Strombus gigas*) utilizaban uno o más de los cinco hábitat evaluados. Se documentó la presencia de langostas espinosas en hábitat de hierbas marinas, mangles y de fondo duro en aguas poco profundas. Asimismo se documentó la presencia de langostas espinosas adultas de tamaño adecuado para pescarlas en hábitat de fondo duro en aguas poco profundas y hábitat de hierbas marinas. La presencia de conchas Reina del Caribe juveniles se documentó sólo en hábitat de hierbas marinas. Si bien se dio alguna variabilidad entre especies de pesca con respecto de la utilización del hábitat, en general, los hábitat de mangles, hierbas marinas y de fondo duro en aguas poco profundas se utilizaron como criaderos para las especies piscícolas juveniles. Por el contrario, el fondo duro en aguas profundas fue utilizado predominantemente por los adultos y hasta cierto punto como áreas de desove. Con la excepción del *Lutjanus analis* (pargo criollo), una especie de pargo de aguas profundas, la mayoría de las especies de pargo y meros utilizaron el hábitat de mangle y/o hierba marina como criadero (Tabla 8 y Apéndice B). El fondo duro de aguas poco profundas también sirvió como hábitat juvenil para algunas especies pesqueras; la utilización del hábitat de fondo duro en aguas poco profundas fue más elevado entre los adultos.

Tabla 8. Presencia documentada de especies de peces e invertebrados selectos de significado comercial y recreativo en los cuatro hábitat compensatorios potenciales por etapa vital (A = adulto y J = juvenil) y actividad de desove reportada (D). El signo A+ indica que las referencias denotan la presencia, pero no indican información sobre la etapa vital.

Especies	Nombre común	Fondo duro poco profundo	Fondo duro profundo	Manglar	Hierba marina
<i>Strombus gigas</i>	Concha Reina del Caribe	A			J, A
<i>Panulirus argus</i>	Langosta espinosa	J, A		J	J, A
<i>Lutjanus griseus</i>	Pargo gris	J, A, S	S	J, A	J, A
<i>Lutjanus vivanus</i>	Pargo criollo	J, A	A		
<i>Lutjanus analis</i>	Mutton snapper	+, S	+, S	J, A	J, A
<i>Ocyurus chrysurus</i>	Colirubia	A	+, S	J, A	J, A
<i>Epinephelus guttatus</i>	Cabrilla	A	+	J	J
<i>Epinephelus striatus</i>	Cherna	A	A	J, A	J

4.0 CONCLUSIONES

Nuestras recomendaciones están basadas en el análisis de datos cualitativos/cuantitativos de presencia/ausencia del hábitat de arrecife eolianita a lo largo de la costa norte de Puerto Rico; la falta de datos cuantitativos limitó el nivel de detalle en el Análisis de Aptitud del Hábitat. La mayoría de los estudios de Puerto Rico, identificados en nuestra investigación bibliográfica, se realizaron en hábitat de arrecifes coralinos a lo largo de la costa suroccidental y no eran aplicables al hábitat de arrecife eolianita presente en el sitio de la encalladura. Pocos estudios se realizaron en áreas cercanas al sitio de la encalladura y los mismos fueron primariamente cualitativos (presencia/ausencia). De manera similar, se encontraron pocos estudios de hábitat de mangles e hierbas marinas que se aplicaban a la costa norte de Puerto Rico. Los datos cuantitativos sobre densidades y parámetros demográficos por tipo de hábitat habrían aumentado grandemente la capacidad del Análisis de Aptitud del Hábitat para hacer predicciones cuantitativas sobre funciones ecológicas (Peterson et al. 2003; Powers et al., 2003); sin embargo, un análisis de ese tipo no era consistente con la información disponible y podría no ser necesario en un caso donde haya acuerdo sobre los daños causados. Aunque es posible que la base de datos actual pudiera aumentarse a través de un nuevo análisis de fotografías y vídeo basado en estudios previos del consejo de fiduciarios o muestreos biológicos específicos del sitio, los análisis adicionales y muestreo podrían ser costosos y no cambiar significativamente las conclusiones del Análisis de Aptitud del Hábitat.

4.1 Recomendaciones

A partir del análisis de la bibliografía, se documentó la presencia de 183 especies en el hábitat de arrecife eolianita. De esas especies, 18 (9,8%) eran únicas al hábitat eolianita, por lo tanto el máximo número de especies del arrecife eolianita sostenidas mediante la utilización de todos los cuatro hábitat compensatorios es 165. La Tabla 9 muestra el número y porcentaje de las especies de arrecife eolianita compartidas con cada uno de los hábitat compensatorios potenciales (Compartidas) y el número de especies de arrecife eolianita compartidas, únicas en cada uno de los hábitat compensatorios (Únicas). Por ejemplo, el hábitat de fondo duro en aguas poco profundas comparte 128 especies con el hábitat de arrecife eolianita y de esas 128 especies de arrecife eolianita compartidas, 42 se encuentran solamente en el hábitat de fondo duro en aguas poco profundas (Tabla 9). La Figura 7 es una parcela de Escalamiento Multidimensional no Métrico que ilustra la similitud entre los hábitat basado en todas las especies eolianitas.

Tabla 9. Número y porcentaje de especies de arrecifes eolianitas compartidas con cada uno de los cuatro hábitat compensatorios potenciales y el número de especies de arrecife eolianita compartidas únicas en cada uno de los hábitat compensatorios.

Especies de arrecife eolianita	Tipo de habitat compensatorio			
	Fondo duro poco profundo	Fondo duro profundo	Manglar	Hierba marina
Compartido	128 (70%)	56 (31%)	68 (37%)	84 (46%)
Único	42 (23%)	7 (3,8%)	8 (4,4%)	9 (4,9%)

Los hábitat se clasificaron de acuerdo con el grado de similitud con respecto al arrecife eolianita según se muestra en las parcelas de Escalamiento Multidimensional no Métricas, así como el número de especies de arrecife eolianita compartidas (Tabla 10). El fondo duro en aguas poco profundas parece tener el grado más alto de similitud, compartiendo 128 especies con el hábitat de arrecife eolianita; y el hábitat de fondo duro en aguas profundas fue el menos similar, con sólo 56 especies compartidas. El hábitat de hierbas marinas, un hábitat importante para el reclutamiento y criadero, se clasificó en segundo lugar en términos de similitud con respecto del arrecife eolianita, compartiendo 46% (84 especies) de las especies del arrecife eolianita. El hábitat de mangle se clasificó en tercer lugar en general. La diferencia de clasificación entre la hierba marina y el mangle es relativamente menor y ambos deben ser considerados similares entre sí en términos de potencial compensatorio. La hierba marina fue la única área utilizada por la concha Reina del Caribe, una especie que causa preocupación significativa en materia de manejo; la hierba marina también proporciona hábitat para dos especies de tortugas marinas comunes a la costa norte de Puerto Rico.

Figura 7. La parcela de escalamiento multidimensional ilustra la similitud de los cinco hábitat basándose en todas las funciones de los hábitat. La tensión indica el grado hasta el cual la parcela representa los datos. Los valores inferiores a 0,1 se consideran altamente representativos.

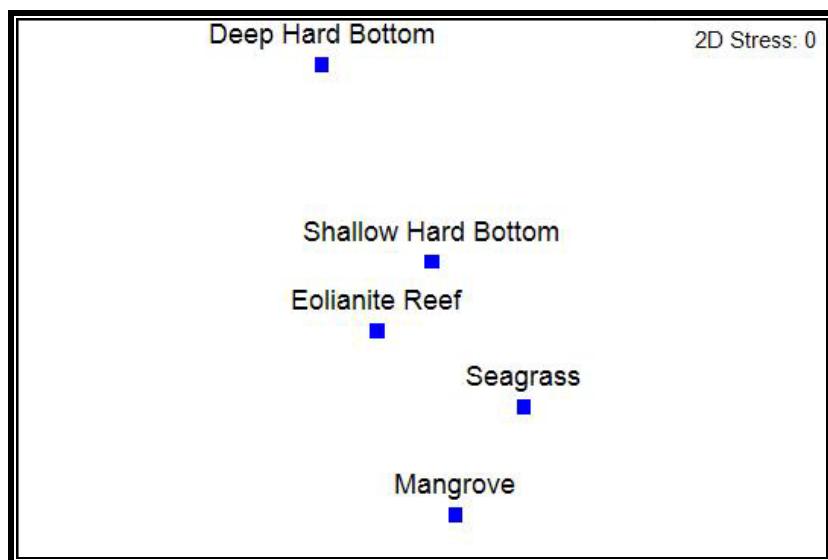


Tabla 10. Clasificaciones relativas de hábitat compensatorios basadas en la similitud de Bray-Curtis de cuatro funciones de hábitat de arrecife eolianita y significación de los hábitat desde el punto de vista de la actividad pesquera.

Significación respecto de las funciones y la industria pesquera	Fondo duro poco profundo	Fondo duro profundo	Hierba marina	Manglar
Producción primaria	66,7	35,3	25,0	35,

Animales estructurales	84,8	34,4	31,8	10,8
Herbívoros	74,3	24,0	77,8	66,7
Predadores	81,0	54,3	73,9	67,6
Hábitat de reclutamiento (Industria pesquera)	Alto	Bajo	Alto	Moderado
Clasificación	1	4	2	3

4.1.1 Fondo duro en aguas poco profundas (de 5 a 10 m)

Al examinar las cuatro categorías de servicio ecológico, el número de especies en común con el arrecife eolianita, y al considerar las especies de significación pesquera, el hábitat de fondo duro en aguas poco profundas mostró la mayor similitud con respecto al hábitat de arrecife eolianita (Tabla 10) y se podría considerar como el hábitat compensatorio más apropiado. Es de esperarse que los arrecifes artificiales creados en las áreas de aguas poco profundas funcionen de modo similar al hábitat dañado, siempre y cuando el diseño de tales arrecifes imite de manera razonable el arrecife eolianita. Sin embargo, las dificultades logísticas asociadas con la construcción a lo largo de la costa norte de Puerto Rico afectada excluiría la restauración *in situ*. Situar arrecifes artificiales dentro de las áreas más protegidas podría ser una alternativa razonable a la restauración *in situ* si el hábitat es creado en proximidad cercana al fondo duro en aguas poco profundas de modo que haya un fondo común de larvas y propagules. Se esperaría que el arrecife artificial creado en áreas protegidas brindaría los mismos beneficios ecológicos que el hábitat de arrecife eolianita.

4.1.2 Hábitat Mosaico

Con respecto a las cuatro funciones, ningún hábitat individual fue idéntico al hábitat dañado: por ello la mejor alternativa sería un enfoque tipo mosaico de restauración compensatoria de más de un hábitat. En muchas áreas la restauración de hábitat adyacentes o cercanos ha demostrado ser eficaz económica y ecológicamente para restaurar la función del hábitat y en proporcionar mejores condiciones para la actividad pesquera (Micheli y Peterson, 1999; Grabowski, 2002; Peterson y Pipcius, 2003). El número de especies de arrecife eolianita comunes a cada hábitat se indican en la Tabla 11. El número de especies de arrecife eolianita para las que se espera un beneficio de la restauración compensatoria de dos tipos de hábitat cercanos se muestra en la Tabla 12. De los dos mosaicos de hábitat compensatorios, el de fondo duro en aguas poco profundas acoplado con un hábitat de hierba marina o uno de mangle de las cercanías brindaría restauración compensatoria para 150 y 149 especies de arrecife eolianita respectivamente. La Tabla 13 muestra el número de especies de arrecife eolianita que se beneficiarían de la restauración compensatoria de tres tipos de hábitat. El Apéndice C proporciona un desglose del número de especies adicionales que se beneficiarían de la adición secuencial de cada tipo de hábitat; comenzando con las especies compartidas proporcionadas por un sólo hábitat compensatorio y añadiendo de manera secuencial hábitat compensatorios y sus especies de arrecife eolianita compartido. El Apéndice C podría ser una herramienta útil para los fines del manejo con el fin de determinar el orden en el cual los hábitat son seleccionados para la restauración compensatoria. La utilización de todos los cuatro hábitat compensatorios arroja 165

especies de arrecife eolianita, independientemente del orden en el que se crean (Apéndice C). La Figura 8 proporciona una representación esquemática de un área de restauración compensatoria antes y a continuación de una restauración compensatoria conjunta. (i.e., inserción de hierba marina y arrecife artificial).

Tabla 11. Número de especies de arrecife eolianita comunes entre hábitat compensatorios.

Hábitat compensatorio	Fondo duro poco profundo	Fondo duro profundo	Manglar	Hierba marina
Fondo duro poco profundo		48	47	62
Fondo duro profundo	48		27	30
Manglar	47	27		53
Hierba marina	62	30	53	

Tabla 12. Número de especies de arrecife eolianita que potencialmente se beneficiarían de un mosaico dado de dos hábitat compensatorios.

Hábitats compensatorios	Fondo duro poco profundo	Fondo duro profundo	Manglar	Hierba marina
Fondo duro poco profundo	-----	136	149	150
Fondo duro profundo	136	-----	97	110
Manglar	149	97	-----	99
Hierba marina	150	110	99	-----

Tabla 13. Número de especies de arrecife eolianita que potencialmente se beneficiarían de un mosaico dado de tres hábitat compensatorios.

Hábitats compensatorios	Fondo duro poco profundo y fondo duro profundo	Manglar y Hierba marina
Fondo duro poco profundo	-----	158
Fondo duro profundo	-----	123
Manglar	156	-----
Hierba marina	157	-----

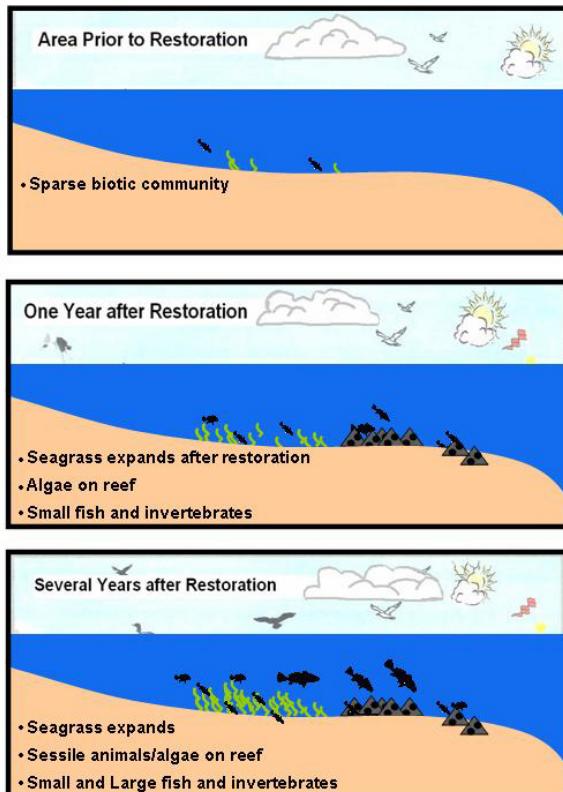


Figura 8. Representación esquemática de un área de restauración compensatoria antes y a continuación de una creación/restauración de un acoplamiento de hierba marina y arrecife artificial.

4.1.2.1 Mosaico de dos hábitat: Fondo duro en aguas poco profundas y hierbas marinas o fondo duro en aguas poco profundas y mangle

Un acoplamiento deseable podría ser la restauración de lechos de hierba marina o manglares cerca de un arrecife artificial en aguas poco profundas, brindando funciones compensatorias a 150 o 149 especies de arrecife eolianita respectivamente. Mayor diversidad y densidad de especies se encuentran en áreas donde los hábitat de hierbas marinas están adyacentes a los hábitat de arrecifes coralinos (Dorenbosch et al., 2004; Nagelkerken y Van der Velde, 2004; Weinstein y Heck, 1979). La yuxtaposición de hierba marina o mangle con el fondo duro imita el paisaje de muchos arrecifes coralinos productivos así como de hábitat en la Bahía de San Juan. El reclutamiento de peces juveniles se ve facilitado por la expansión de lechos de hierbas marinas o de hábitat de manglares en aguas poco profundas que proporcionan abrigo contra los predadores y brindan fuentes abundantes de alimentos. Además, los lechos de hierbas marinas pueden proporcionar áreas de criaderos para larvas de peces planctónicos con mayor eficacia que los arrecifes, que son utilizados por los especímenes juveniles y adultos de edad más avanzada (Powers et al., 2003). Los hábitat de hierba marina y mangle son áreas de criadero para muchos peces de arrecifes. Los especímenes juveniles de *Haemulon flavolineatum*, *H. sciurus*, *Lutjanus analis*, *L. apodus*, *L. mahogoni*, *Ocyurus chrysurus*, *Acanthurus chigurhus*, *Scarus coeruleus* y *Sphyraena barracuda* se encuentran predominantemente en lechos de hierbas marinas mientras que los especímenes juveniles de *L. apodus*, *L. griseus*, *S. barracuda* y *Chaetodon capistratus* son algunas de las especies más comúnmente encontradas en manglares (Nagelkerken et al., 2000). Muchos peces juveniles en los lechos de hierbas marinas y manglares experimentan un cambio de hábitat ontogenético a medida que dejan atrás la protección proporcionada por el hábitat juvenil y migran hacia hábitat de arrecifes cercanos (Weinstein y Heck, 1979; Nagelkerken et al., 2000; Cocheret de la Moriniere et al., 2002). Un arrecife artificial cercano que imita el hábitat de fondo duro natural proporcionaría hábitat para adultos y podría estabilizar el lecho de hierba marina o el hábitat de mangle y protegerlo de la acción de las olas y el transporte de sedimentos. Crear un hábitat de mosaico de lechos de hierba marina o manglares y arrecifes artificiales proporcionaría hábitat juvenil y adulto para especies asociadas con el hábitat de arrecife eolianita dañado por la encalladura del Morris J. Berman.

4.1.2.2 Mosaico de tres hábitat: fondo duro en aguas poco profundas, hierbas marinas y manglares

La restauración compensatoria de hábitat de fondos duros en aguas poco profundas, de hierbas marinas y de manglares dentro de un área lagunal proporcionaría funciones compensatorias a 86% de especies de arrecife eolianita que fueron afectadas directa o indirectamente por la encalladura. La restauración compensatoria combinada de estos tres hábitat proporcionaría hábitat para muchos de los especímenes juveniles y adultos de las especies predadoras y herbívoras cuya presencia se ha documentado en el arrecife eolianita. Añadir el tercer tipo de hábitat a los dos mosaicos de hábitat mencionados anteriormente, compensaría por nueve (9) especies adicionales únicas de hierbas marinas u ocho (8) especies de manglares únicas (Sección 4.1.3).

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APPENDICES

APPENDIX A
EVALUATED LITERATURE SOURCES

PRIMARY LITERATURE:
(High Quality)

The following literature cited includes refereed book chapters, articles published in peer-reviewed journals, Master of Science Theses, and Doctoral Dissertations.

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APPENDIX B

DOCUMENTED SPECIES LIST

Table B. Species documented along the north coast of Puerto Rico for each of the five evaluated habitats. Service category, a general description and presence absence is designated for each species. Presence/absence designations are as follows: + indicates present; J indicates that juveniles utilize the habitat; A indicates that adults utilize the habitat; and S indicates that the habitat is utilized for spawning.

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Acetabularia crenulata</i>	Primary Producer	Green algae		+		+	
<i>Anadyomene stellata</i>	Primary Producer	Green algae		+	+	+	
<i>Avrainvillea asarifolia</i>	Primary Producer	Green algae		+	+	+	
<i>Avrainvillea longicaulis</i>	Primary Producer	Green algae		+	+	+	+
<i>Avrainvillea nigricans</i>	Primary Producer	Green algae		+	+		
<i>Avrainvillea rawsonii</i>	Primary Producer	Green algae		+	+		
<i>Avrainvillea silvana</i>	Primary Producer	Green algae		+	+	+	
<i>Bryopsis hypnoides</i>	Primary Producer	Green algae		+		+	
<i>Bryopsis pennata</i>	Primary Producer	Green algae		+		+	
<i>Caulerpa ashmeadii</i>	Primary Producer	Green algae		+		+	+
<i>Caulerpa mexicana</i>	Primary Producer	Green algae	+	+		+	+
<i>Caulerpa microphysa</i>	Primary Producer	Green algae		+	+		
<i>Caulerpa prolifera</i>	Primary Producer	Green algae	+				+
<i>Caulerpa racemosa</i>	Primary Producer	Green algae		+	+	+	+
<i>Caulerpa sertularioides</i>	Primary Producer	Green algae		+		+	+
<i>Caulerpa taxifolia</i>	Primary Producer	Green algae		+		+	
<i>Caulerpa verticillata</i>	Primary Producer	Green algae		+		+	+
<i>Caulerpa webbiana</i>	Primary Producer	Green algae		+	+		
<i>Caulerpa ambigua</i>	Primary Producer	Green algae					
<i>Chaetomorpha aerea</i>	Primary Producer	Green algae		+			
<i>Chaetomorpha antennina</i>	Primary Producer	Green algae		+			
<i>Chaetomorpha brachygona</i>	Primary Producer	Green algae					
<i>Chaetomorpha clavata</i>	Primary Producer	Green algae		+			
<i>Chaetomorpha linum</i>	Primary Producer	Green algae		+			
<i>Chamaedoris peniculum</i>	Primary Producer	Green algae		+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Cladocephalus luteofuscus</i>	Primary Producer	Green algae					+
<i>Cladophora catenata</i>	Primary Producer	Green algae		+			
<i>Cladophora conferta</i>	Primary Producer	Green algae					
<i>Cladophora montagnei</i>	Primary Producer	Green algae					
<i>Cladophora prolifera</i>	Primary Producer	Green algae		+			
<i>Cladophora socialis</i>	Primary Producer	Green algae					
<i>Cladophora submarina</i>	Primary Producer	Green algae					
<i>Cladophora vagabunda</i>	Primary Producer	Green algae					
<i>Cladophoropsis membranacea</i>	Primary Producer	Green algae					+
<i>Codium decorticatum</i>	Primary Producer	Green algae		+			
<i>Codium intertextum</i>	Primary Producer	Green algae		+			
<i>Codium isthmocladum</i>	Primary Producer	Green algae		+	+	+	
<i>Cymopolia barbata</i>	Primary Producer	Green algae		+			
<i>Dictyosphaeria cavernosa</i>	Primary Producer	Green algae		+	+		
<i>Dictyosphaeria ocellata</i>	Primary Producer	Green algae		+			+
<i>Enteromorpha</i> sp.	Primary Producer	Green algae	+	+		+	+
<i>Enteromorpha lingulata</i>	Primary Producer	Green algae		+		+	+
<i>Enteromorpha flexuosa</i>	Primary Producer	Green algae		+		+	+
<i>Halimeda discoidea</i>	Primary Producer	Green algae		+	+		
<i>Halimeda gracilis</i>	Primary Producer	Green algae		+	+	+	
<i>Halimeda hummii</i>	Primary Producer	Green algae		+			
<i>Halimeda incrassa</i>	Primary Producer	Green algae		+		+	+
<i>Halimeda monile</i>	Primary Producer	Green algae		+			+
<i>Halimeda opuntia</i>	Primary Producer	Green algae		+	+	+	+
<i>Penicillus capitatus</i>	Primary Producer	Green algae		+		+	+
<i>Penicillus dumetosus</i>	Primary Producer	Green algae		+			+
<i>Penicillus pyriformis</i>	Primary Producer	Green algae		+			
<i>Rhizoclonium riparium</i>	Primary Producer	Green algae		+			
<i>Udotea abbottiorum</i>	Primary Producer	Green algae		+			+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Udotea conglutinata</i>	Primary Producer	Green algae		+	+		
<i>Udotea cyathiformis</i>	Primary Producer	Green algae		+	+	+	
<i>Udotea flabellum</i>	Primary Producer	Green algae		+			+
<i>Ulva lactuca</i>	Primary Producer	Green algae	+	+			
<i>Ventricaria ventricosa</i>	Primary Producer	Green algae		+	+	+	
<i>Halodule wrightii</i>	Primary Producer	Seagrass					+
<i>Syringodium filiforme</i>	Primary Producer	Seagrass					+
<i>Thalassia testudinum</i>	Primary Producer	Seagrass					+
<i>Acanthophora muscoides</i>	Primary Producer	Red algae		+	+		
<i>Acanthophora spicifera</i>	Primary Producer	Red algae	+	+		+	
<i>Acrochaetium flexuosum</i>	Primary Producer	Red algae					+
<i>Agardhiella ramosissima</i>	Primary Producer	Red algae		+	+		
<i>Agardhiella subulata</i>	Primary Producer	Red algae			+		
<i>Aglaothamnion boergesenii</i>	Primary Producer	Red algae					
<i>Aglaothamnion cordatum</i>	Primary Producer	Red algae			+		
<i>Amansia multifida</i>	Primary Producer	Red algae	+	+			
<i>Amphiroa fragilissima</i>	Primary Producer	Red algae			+		+
<i>Amphiroa rigida</i>	Primary Producer	Red algae		+			+
<i>Amphiroa</i> spp.	Primary Producer	Articulated red algae	+	+			+
<i>Antithamnionella breviramosa</i>	Primary Producer	Red algae			+		
<i>Apoglossum gregarium</i>	Primary Producer	Red algae					
<i>Asparagopsis taxiformis</i>	Primary Producer	Red algae			+	SP	
<i>Asteromenia peltata</i>	Primary Producer	Red algae					
<i>Bostrychia tenella</i>	Primary Producer	Red algae		+		+	
<i>Botryocladia occidentalis</i>	Primary Producer	Red algae			+		
<i>Bryocladia cuspidata</i>	Primary Producer	Red algae					
<i>Bryothamnion seaforthii</i>	Primary Producer	Red algae					
<i>Bryothamnion triquetrum</i>	Primary Producer	Red algae		+	+		
<i>Caloglossa leprieurii</i>	Primary Producer	Red algae		+		+	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Catenella caespitosa</i>	Primary Producer	Red algae		+		+	
<i>Centroceras clavulatum</i>	Primary Producer	Red algae		+		+	
<i>Ceramium cruciatum</i>	Primary Producer	Red algae					
<i>Ceramium fastigiatum</i>	Primary Producer	Red algae					
<i>Ceramium flaccidum</i>	Primary Producer	Red algae					+
<i>Ceramium nitens</i>	Primary Producer	Red algae				+	
<i>Champia parvula</i>	Primary Producer	Red algae			+		+
<i>Champia salicornioides</i>	Primary Producer	Red algae			+		+
<i>Champia vieillardii</i>	Primary Producer	Red algae		+			+
<i>Chondria littoralis</i>	Primary Producer	Red algae			+		
<i>Chondria polyrhiza</i>	Primary Producer	Red algae			+		
<i>Chrysymenia nodulosa</i>	Primary Producer	Red algae			+		
<i>Coelothrix irregularis</i>	Primary Producer	Red algae	+	+		+	
<i>Corallina panizzoi</i>	Primary Producer	Red algae					
<i>Crouania attenuata</i>	Primary Producer	Red algae			+		
<i>Cryptonemia crenulata</i>	Primary Producer	Red algae		+	+		
<i>Cryptonemia luxurians</i>	Primary Producer	Red algae			+		
<i>Dasya baillouviana</i>	Primary Producer	Red algae			+		+
<i>Dasya mollis</i>	Primary Producer	Red algae			+		
<i>Dasya puertoricensis</i>	Primary Producer	Red algae			+		
<i>Dictyurus occidentalis</i>	Primary Producer	Red algae	+	+	+		
<i>Digenia simplex</i>	Primary Producer	Red algae		+	+		
<i>Diplothamnion jolyi</i>	Primary Producer	Red algae					
<i>Dipterosiphonia dendritica</i>	Primary Producer	Red algae					
<i>Dohrnilla antillara</i>	Primary Producer	Red algae					
<i>Enantiocladia duperreyi</i>	Primary Producer	Red algae					
<i>Galaxaura marginata</i>	Primary Producer	Red algae		+		+	
<i>Galaxaura obtusata</i>	Primary Producer	Red algae		+		+	
<i>Galaxaura rugosa</i>	Primary Producer	Red algae		+		+	
<i>Gelidiella acerosa</i>	Primary Producer	Red algae		+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Gelidium americanum</i>	Primary Producer	Red algae		+			
<i>Gelidium pusillum</i>	Primary Producer	Red algae		+			
<i>Gelidium spinosum</i>	Primary Producer	Red algae					
<i>Gracilaria</i> sp.	Primary Producer	Red algae	+	+	+		
<i>Gracilaria curtissiae</i>	Primary Producer	Red algae		+			
<i>Gracilaria domingensis</i>	Primary Producer	Red algae			+		
<i>Grateloupia dichotoma</i>	Primary Producer	Red algae					
<i>Griffithsia globulifera</i>	Primary Producer	Red algae		+			
<i>Gymnogongrus tenuis</i>	Primary Producer	Red algae					
<i>Haliptilon cubense</i>	Primary Producer	Red algae			+		
<i>Haliptilon subulatum</i>	Primary Producer	Red algae		+			
<i>Haloplegma duperreyi</i>	Primary Producer	Red algae			+		
<i>Halydictyon mirabile</i>	Primary Producer	Red algae		+			+
<i>Halymenia floresia</i>	Primary Producer	Red algae		+	+		
<i>Helminthocladia calvadosii</i>	Primary Producer	Red algae					
<i>Herposiphonia secunda</i>	Primary Producer	Red algae		+			
<i>Heterosiphonia crispella</i>	Primary Producer	Red algae			+	+	
<i>Heterosiphonia gibbesii</i>	Primary Producer	Red algae			+	+	
<i>Hypnea musciformis</i>	Primary Producer	Red algae	+		+		
<i>Hypnea spinella</i>	Primary Producer	Red algae			+		
<i>Hypnea volubilis</i>	Primary Producer	Red algae					
<i>Hypoglossum anomalum</i>	Primary Producer	Red algae					
<i>Hypoglossum rhizophorum</i>	Primary Producer	Red algae			+		
<i>Hypoglossum simulans</i>	Primary Producer	Red algae					
<i>Jania adhaerens</i>	Primary Producer	Red algae		+	+	+	
<i>Jania capillacea</i>	Primary Producer	Red algae		+			+
<i>Jania rubens</i>	Primary Producer	Red algae		+	+		
<i>Laurencia corallopis</i>	Primary Producer	Red algae					
<i>Laurencia gemmifera</i>	Primary Producer	Red algae		+	+		
<i>Laurencia intricata</i>	Primary Producer	Red algae		+		+	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Laurencia microcladia</i>	Primary Producer	Red algae		+			
<i>Laurencia obtusa</i>	Primary Producer	Red algae		+			
<i>Laurencia papillosa</i>	Primary Producer	Red algae		+			
<i>Laurencia poiteaui</i>	Primary Producer	Red algae			+		
<i>Liagora pinnata</i>	Primary Producer	Red algae					
<i>Liagoropsis schrammii</i>	Primary Producer	Red algae		+			
<i>Lithophyllum daedaleum</i>	Primary Producer	Red algae		+			
<i>Lithophyllum intermedium</i>	Primary Producer	Red algae					
<i>Lithophyllum prototypum</i>	Primary Producer	Red algae					
<i>Melobesia membranacea</i>	Primary Producer	Red algae					
<i>Meristiella gelidium</i>	Primary Producer	Red algae					
<i>Micropeuce mucronata</i>	Primary Producer	Red algae					
<i>Mesophyllum aemulans</i>	Primary Producer	Red algae					
<i>Murrayella periclados</i>	Primary Producer	Red algae		+		+	
<i>Neogoniolithon accretum</i>	Primary Producer	Red algae					
<i>Neogoniolithon strictum</i>	Primary Producer	Red algae		+			
<i>Ochtones secundiramea</i>	Primary Producer	Red algae			+		
<i>Osmundaria obtusiloba</i>	Primary Producer	Red algae		+			
<i>Peyssonnelia</i> sp.	Primary Producer	Red algae	+	+	+		
<i>Peyssonnelia rubra</i>	Primary Producer	Red algae		+	+		
<i>Pleonosporium caribaeum</i>	Primary Producer	Red algae					
<i>Polysiphonia atlantica</i>	Primary Producer	Red algae		+			
<i>Polysiphonia ferulacea</i>	Primary Producer	Red algae		+	+		
<i>Polysiphonia howei</i>	Primary Producer	Red algae		+			
<i>Predaea feldmanii</i>	Primary Producer	Red algae			+		
<i>Predaea goffiana</i>	Primary Producer	Red algae					
<i>Predaea weldii</i>	Primary Producer	Red algae					
<i>Pterocladiella capillacea</i>	Primary Producer	Red algae		+			
<i>Scinaia complanata</i>	Primary Producer	Red algae			+		
<i>Soliera filiformis</i>	Primary Producer	Red algae		+	+		

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Spermothamnion investiens</i>	Primary Producer	Red algae					
<i>Spyridia clavata</i>	Primary Producer	Red algae					
<i>Spyridia filamentosa</i>	Primary Producer	Red algae		+			
<i>Tiffaniella gorgonea</i>	Primary Producer	Red algae			+		
<i>Trichogloea requienii</i>	Primary Producer	Red algae			+		
<i>Tricleocarpa fragilis</i>	Primary Producer	Red algae			+		
<i>Wrangelia argus</i>	Primary Producer	Red algae		+			
<i>Wrangelia penicillata</i>	Primary Producer	Red algae		+	+	+	
<i>Wurdemannia miniata</i>	Primary Producer	Red algae		+	+	+	
<i>Colpomenia sinuosa</i>	Primary Producer	Brown algae		+			
<i>Dictyopteris</i> sp.	Primary Producer	Brown algae	+	+	+	+	
<i>Dictyopteris delicatula</i>	Primary Producer	Brown algae		+		+	
<i>Dictyopteris jamaicensis</i>	Primary Producer	Brown algae		+	+		
<i>Dictyopteris justii</i>	Primary Producer	Brown algae		+	+		
<i>Dictyota</i> sp.	Primary Producer	Brown algae	+	+	+	+	+
<i>Dictyota alternans</i>	Primary Producer	Brown algae		+	+		
<i>Dictyota bartayresiana</i>	Primary Producer	Brown algae		+		+	
<i>Dictyota cervicornis</i>	Primary Producer	Brown algae		+		+	+
<i>Dictyota ciliolata</i>	Primary Producer	Brown algae		+	+		
<i>Dictyota guineensis</i>	Primary Producer	Brown algae		+			
<i>Dictyota menstrualis</i>	Primary Producer	Brown algae			+		
<i>Dictyota mertensii</i>	Primary Producer	Brown algae		+			
<i>Dictyota pulchella</i>	Primary Producer	Brown algae		+	+	+	+
<i>Hincksia breviarticulata</i>	Primary Producer	Brown algae					
<i>Hincksia mitchelliae</i>	Primary Producer	Brown algae		+		+	
<i>Lobophora variegata</i>	Primary Producer	Brown algae		+	+	+	
<i>Nereia tropica</i>	Primary Producer	Brown algae			+		
<i>Padina boergesenii</i>	Primary Producer	Brown algae		+		+	
<i>Padina gymnospora</i>	Primary Producer	Brown algae		+		+	
<i>Padina sanctae-crucis</i>	Primary Producer	Brown algae		+		+	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Ralfsia expansa extensa</i>	Primary Producer	Brown algae		+			
<i>Sargassum fluitans</i>	Primary Producer	Brown algae	pelagic				
<i>Sargassum hystrix</i>	Primary Producer	Brown algae		+	+		
<i>Sargassum natans</i>	Primary Producer	Brown algae	pelagic				
<i>Sargassum platycarpum</i>	Primary Producer	Brown algae		+			
<i>Sargassum polyceratum</i>	Primary Producer	Brown algae		+			
<i>Sargassum rigidulum</i>	Primary Producer	Brown algae					
<i>Sargassum vulgare</i>	Primary Producer	Brown algae		+		+	
<i>Spatoglossum schroederi</i>	Primary Producer	Brown algae			+		
<i>Sphacelaria tribuloides</i>	Primary Producer	Brown algae		+		+	
<i>Sporochnus bolleanus</i>	Primary Producer	Brown algae					
<i>Styropodium zonale</i>	Primary Producer	Brown algae		+	+		
<i>Turbinaria tricostata</i>	Primary Producer	Brown algae		+			
<i>Turbinaria turbinata</i>	Primary Producer	Brown algae		+			
<i>Briareum</i> sp.	Structural Animal	Soft coral		+			
<i>Eunicea</i> sp.	Structural Animal	Soft coral	+	+	+		
<i>Gorgonia flabellum</i>	Structural Animal	Soft coral		+			+
<i>Gorgonia</i> spp.	Structural Animal	Soft coral	+	+			+
<i>Gorgonia ventalina</i>	Structural Animal	Soft coral	+	+			
<i>Millepora alcicornis</i>	Structural Animal	Soft coral		+			+
<i>Millepora complanata</i>	Structural Animal	Soft coral		+			
<i>Millepora squarrosa</i>	Structural Animal	Soft coral		+			
<i>Muricea muricata</i>	Structural Animal	Soft coral	+	+			
<i>Plexaura flexuosa</i>	Structural Animal	Soft coral	+	+			
<i>Plexaura homamalla</i>	Structural Animal	Soft coral		+			
<i>Plexaurella</i> sp.	Structural Animal	Soft coral	+	+			
<i>Pseudoplexaura</i> sp.	Structural Animal	Soft coral	+	+			
<i>Pseudopterogorgia</i> sp.	Structural Animal	Soft coral		+	+		
<i>Pterogorgia citrina</i>	Structural Animal	Soft coral		+			
<i>Acropora cervicornis</i>	Structural Animal	Hard coral		+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Acropora palmata</i>	Structural Animal	Hard coral		+			
<i>Agaricia agaricites</i>	Structural Animal	Hard coral		+	+	+	
<i>Agaricia tenuifolia</i>	Structural Animal	Hard coral					
<i>Dendrogyra cylindrus</i>	Structural Animal	Hard coral		+	+		
<i>Dichocoenia stokesi</i>	Structural Animal	Hard coral		+			
<i>Diploria clivosa</i>	Structural Animal	Hard coral	+	+		+	+
<i>Diploria labyrinthiformis</i>	Structural Animal	Hard coral	+	+			
<i>Diploria</i> sp.	Structural Animal	Hard coral	+	+	+	+	+
<i>Diploria strigosa</i>	Structural Animal	Hard coral	+	+	+	+	+
<i>Favia cf. gravida</i>	Structural Animal	Hard coral		+			
<i>Favia fragum</i>	Structural Animal	Hard coral		+		+	+
<i>Helioceris cucullata</i> (<i>Leptoseris cucullata</i>)	Structural Animal	Hard coral		+	+		
<i>Isophyllia multiflora</i>	Structural Animal	Hard coral		+			
<i>Isophyllia sinuosa</i>	Structural Animal	Hard coral		+	+		
<i>Manicina areolata</i>	Structural Animal	Hard coral		+			+
<i>Meandrina meandrites</i>	Structural Animal	Hard coral	+	+	+		
<i>Montastraea annularis</i>	Structural Animal	Hard coral	+	+			
<i>Montastraea cavernosa</i>	Structural Animal	Hard coral	+	+	+		
<i>Porites astreoides</i>	Structural Animal	Hard coral	+	+			+
<i>Porites porites</i>	Structural Animal	Hard coral	+	+			+
<i>Siderastrea radians</i>	Structural Animal	Hard coral	+	+			
<i>Siderastrea siderea</i>	Structural Animal	Hard coral	+	+			+
<i>Stephanocoenia</i> sp.	Structural Animal	Hard coral	+		+		
<i>Agelas clathrodes</i>	Structural Animal	Sponge	+		+		
<i>Amphimedon compressa</i>	Structural Animal	Sponge	+				
<i>Anthosigmella varians</i>	Structural Animal	Sponge	+	+			
<i>Aplysina fistularis</i>	Structural Animal	Sponge	+				
<i>Callyspongia fallax</i>	Structural Animal	Sponge	+				
<i>Callyspongia vaginalis</i>	Structural Animal	Sponge	+	+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 – 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Chodrilla nucula</i>	Structural Animal	Sponge	+	+			
<i>Cliona delitrix</i>	Structural Animal	Sponge	+				
<i>Cliona langae</i>	Structural Animal	Sponge	+				
<i>Desmapsamma anchorata</i>	Structural Animal	Sponge	+	+			
<i>Ectyoplasia ferox</i>	Structural Animal	Sponge	+				
<i>Holopsamma helwigi</i>	Structural Animal	Sponge	+				
<i>Ircinia campana</i>	Structural Animal	Sponge	+	+	+		
<i>Ircinia strobilina</i>	Structural Animal	Sponge	+	+			
<i>Iricinia felix</i>	Structural Animal	Sponge	+			+	+
<i>Leucetta floridana</i>	Structural Animal	Sponge	+				
<i>Monanachora barbadensis</i>	Structural Animal	Sponge	+				
<i>Niphates erecta</i>	Structural Animal	Sponge	+	+			
<i>Pseudaxinella lunaecharta</i>	Structural Animal	Sponge	+	+			+
<i>Pseudoceratina crassa</i>	Structural Animal	Sponge	+				
<i>Spinosella vaginalis</i>	Structural Animal	Sponge	+	+	+		
<i>Spirastrella</i> sp.	Structural Animal	Sponge	+				
<i>Verongula gigantea</i>	Structural Animal	Sponge	+	+			
<i>Xestospongia muta</i>	Structural Animal	Sponge	+	+	+		
<i>Ricordea florida</i>	Structural Animal	Corallimorph	+	+			
<i>Halocordyle disticha</i>	Structural Animal	Hydroid	+	+			
<i>Palythoa caribboea</i>	Structural Animal	Zoanthid	+	+			
<i>Palythoa</i> sp.	Structural Animal	Zoanthid		+			
<i>Zoanthus sociatus</i>	Structural Animal	Zoanthid	+				
<i>Zoanthus</i> sp.	Structural Animal	Zoanthid	+	+			
<i>Diadema antillarum</i>	Herbivorous Invert.	Urchin	+	+			J, A
<i>Diadema reticulatum</i>	Herbivorous Invert.	Urchin	+				+
<i>Echinometra lucunter</i>	Herbivorous Invert.	Urchin	+				+
<i>Lytechinus variegatus</i>	Herbivorous Invert.	Urchin	+				+
<i>Tripneustes ventricosus</i>	Herbivorous Invert.	Urchin	+				
<i>Tripneustes esculentus</i>	Herbivorous Invert.	Urchin	+	+			+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Panulirus argus</i>	Predatory Invertebrate	Spiny Lobster	+	J, A		J	J, A
<i>Strombus gigas</i>	Herbivorous Invert.	Queen Conch		A			J, A, S
<i>Chelonia mydas</i>	Herbivorous Vertebrate	Turtle	+				+
<i>Eretmochelys imbricata</i>	Herbivorous Vertebrate	Turtle		+	+	+	
<i>Dermochelys coriacea</i>	Herbivorous Vertebrate	Turtle			+		
<i>Caretta caretta</i>	Herbivorous Vertebrate	Turtle		+			
<i>Ginglymostoma cirratum</i>	Predatory vertebrate	Predatory reef shark				+	+
<i>Negaprion brevirostris</i>	Predatory vertebrate	Predatory reef shark	+			J, A	
<i>Carcharhinus leucas</i>	Predatory vertebrate	Predatory reef shark	+			J	
<i>Carcharhinus limbatus</i>	Predatory vertebrate	Predatory reef shark	+			J, A	
<i>Dasyatis sp.</i>	Predatory vertebrate	Predatory reef fish		+	+	+	+
<i>Aetobatus narinari</i>	Predatory vertebrate	Predatory reef fish				A	
<i>Megalops atlanticus</i>	Predatory vertebrate	Predatory pelagic fish				J, A	J
<i>Elops saurus</i>	Predatory vertebrate	Predatory seagrass fish	+			J, A	+
<i>Albula vulpes</i>	Predatory vertebrate	Predatory seagrass fish	+				A
<i>Anguilla rostrata</i>	Predatory vertebrate	Predatory benthic eel				A	
<i>Enchelycore nigricans</i>	Predatory vertebrate	Predatory reef fish	+	+			
<i>Gymnothorax moringa</i>	Predatory vertebrate	Predatory reef fish		+			+
<i>Moringua edwardsi</i>	Predatory vertebrate	Predatory zoobenthic reef fish				A	
<i>Myrophis punctatus</i>	Predatory vertebrate	Predatory zoobenthic reef fish				+	
<i>Conger triporiceps</i>	Predatory vertebrate	Predatory mangrove fish				A	
<i>Sardinella sp.</i>	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder		A		A	+
<i>Harengula humeralis</i>	Predatory vertebrate	Planktivorous pelagic fish/filter feeder				A	
<i>Opisthonema oglinum</i>	Predatory vertebrate	Predatory mangrove fish				J, A	
<i>Anchoa parva or filifera</i>	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder				A	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Anchoa hepsetus</i>	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder				+	+
<i>Cetengraulis edentulus</i>	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder	+			A	
<i>Synodus foetens</i>	Predatory vertebrate	Predatory reef fish	+			+	+
<i>Lepophidium</i> spp.	Predatory vertebrate	Predatory reef fish	+				
<i>Arcos macropthalmus</i>	Predatory vertebrate	Predatory reef fish	+	+			
<i>Hemiramphus brasiliensis</i>	Predatory vertebrate	Planktivorous pelagic fish/filter feeder	+	+			+
<i>Hyporhamphus unifasciatus</i>	Predatory vertebrate	Planktivorous reef fish/filter feeder	+			A	+
<i>Strongylura notata</i>	Predatory vertebrate	Predatory fish	+			J	
<i>Strongylura timucu</i>	Predatory vertebrate	Predatory fish				J, A	
<i>Tylosurus</i> sp.	Predatory vertebrate	Predatory reef fish	+	+			+
<i>Platybelone argalus</i>	Predatory vertebrate	Predatory seagrass fish	+				
<i>Atherinomorus stipes</i>	Predatory Fish	Zooplanktivorous reef fish				J, A	
<i>Holocentrus ascensionis</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+	A	A	+(night)	A
<i>Holocentrus coruscus</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+				
<i>Holocentrus rufus</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+	+	A	A	+
<i>Holocentrus vexillarius</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+	+			
<i>Plectrypops retrospinis</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+		+		
<i>Myripristis jacobus</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+	+			
<i>Neoniphon marianus</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+		+		
<i>Aulostomus maculatus</i>	Predatory vertebrate	Predatory reef fish	+	+			+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Fistularia tabacaria</i>	Predatory vertebrate	Predatory reef fish	+				+
<i>Syngnathus dunckeri</i>	Predatory vertebrate	Predatory reef fish				A	J, A
<i>Syngnathus pelagicus</i>	Predatory vertebrate	Predatory reef fish					J, A
<i>Dactylopterus volitans</i>	Predatory vertebrate	Predatory zoobenthic reef fish					J
<i>Scorpaena plumieri</i>	Predatory vertebrate	Predatory reef fish	+				J
<i>Scorpaenodes caribbaeus</i>	Predatory vertebrate	Predatory reef fish	+	+			
<i>Scorpaenopsis grandicornis</i>	Predatory vertebrate	Predatory reef fish				J	A
<i>Sebastes melanops</i>	Predatory vertebrate	Predatory reef fish	+				
<i>Centropomus enciferus</i>	Predatory vertebrate	Predatory reef fish				J, A	
<i>Centropomus parallelus</i>	Predatory vertebrate	Predatory reef fish				+	
<i>Centropomus undecimalis</i>	Predatory vertebrate	Predatory reef fish				J, A	+
<i>Centropomus pectinatus</i>	Predatory vertebrate	Predatory reef fish				J	
<i>Epinephelus</i> spp.	Predatory vertebrate	Predatory reef fish	+				
<i>Epinephelus adscensionis</i>	Predatory vertebrate	Predatory reef fish	+	+	+		
<i>Epinephelus fulvus</i>	Predatory vertebrate	Predatory reef fish	+	A	A		A
<i>Epinephelus guttatus</i>	Predatory vertebrate	Predatory reef fish	+	A	+	J	J
<i>Epinephelus morio</i>	Predatory vertebrate	Predatory reef fish	+	+	+		J
<i>Epinephelus striatus</i>	Predatory vertebrate	Predatory reef fish		A	A	J, A	J
<i>Priacanthus arenatus</i>	Predatory vertebrate	Predatory reef fish	+		+		
<i>Apogon maculatus</i>	Predatory vertebrate	Predatory reef fish	+	+			
<i>Malacanthus plumieri</i>	Predatory vertebrate	Predatory reef fish	+	A	+		
<i>Oligoplites saurus</i>	Predatory vertebrate	Planktivorous pelagic fish/filter feeder				J	
<i>Caranx</i> sp.	Predatory vertebrate	Predatory pelagic fish	+				
<i>Caranx bartholomaei</i>	Predatory vertebrate	Predatory pelagic fish		J, A	A		+
<i>Caranx hippos</i>	Predatory vertebrate	Predatory pelagic fish				J	
<i>Caranx ruber</i>	Predatory vertebrate	Predatory pelagic fish	+	J, A		A	A
<i>Caranx latus</i>	Predatory vertebrate	Predatory pelagic fish				J, A	A
<i>Selar crumenophthalmus</i>	Predatory vertebrate	Predatory pelagic fish	+	+			+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Selene vomer</i>	Predatory vertebrate	Predatory pelagic fish		+			+
<i>Trachinotus falcatus</i>	Predatory vertebrate	Predatory pelagic fish				J	A
<i>Trachinotus goodei</i>	Predatory vertebrate	Predatory pelagic fish				J	
<i>Lutjanus analis</i>	Predatory vertebrate	Predatory reef fish		+, S	+, S	J, A	J, A
<i>Lutjanus apodus</i>	Predatory vertebrate	Predatory reef fish	+	J, A	+, S	J, A	J, A
<i>Lutjanus cyanopterus</i>	Predatory vertebrate	Predatory reef fish	+		S	J	J
<i>Lutjanus griseus</i>	Predatory vertebrate	Predatory reef fish	+	J, A, S	S	J, A	J, A
<i>Lutjanus jocu</i>	Predatory vertebrate	Predatory reef fish	+	+	S	J, A	J, A
<i>Lutjanus mahogoni</i>	Predatory vertebrate	Predatory reef fish	+	+	+	J	J, A
<i>Lutjanus synagris</i>	Predatory vertebrate	Predatory reef fish	+	+	+, S	J, A	J, A, S
<i>Lutjanus vivanus</i>	Predatory vertebrate	Predatory reef fish		J, A	A		
<i>Ocyurus chrysurus</i>	Predatory vertebrate	Predatory reef fish	+	A	+, S	J, A	J, A
<i>Gerres cinereus</i>	Predatory vertebrate	Predatory reef fish	+	J	+	J, A	+
<i>Eugerres plumieri</i>	Predatory vertebrate	Predatory reef fish/ Micorcrustacean feeder				J, A	
<i>Eucinostomus argenteus</i>	Predatory vertebrate	Predatory zoobenthic fish	+			J	+
<i>Eucinostomus gula</i>	Predatory vertebrate	Predatory zoobenthic fish				J	+
<i>Eucinostomus lefroyi</i>	Predatory vertebrate	Predatory zoobenthic fish				J	+
<i>Eucinostomus melanopterus</i>	Predatory vertebrate	Predatory zoobenthic fish				J	
<i>Diapterus olistostomus</i>	Predatory vertebrate	Predatory zoobenthic fish				J	
<i>Diapterus rhombus</i>	Predatory vertebrate	Predatory zoobenthic fish				J	+
<i>Anisotremus surinamensis</i>	Predatory vertebrate	Predatory reef fish	+	A	+		
<i>Anisotremus virginicus</i>	Predatory vertebrate	Predatory reef fish	+	+	+	J	J
<i>Haemulon album</i>	Predatory vertebrate	Predatory reef fish	+	+		J, A	+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Haemulon aurolineatum</i>	Predatory vertebrate	Predatory reef fish	+	J	+	J, A	J, A
<i>Haemulon bonariensis</i>	Predatory vertebrate	Predatory reef fish	+			A	J
<i>Haemulon chrysargyreum</i>	Predatory vertebrate	Predatory reef fish	+	+	+		J
<i>Haemulon flavolineatum</i>	Predatory vertebrate	Predatory reef fish	+	A	+	J, A	J, A
<i>Haemulon plumieri</i>	Predatory vertebrate	Predatory reef fish	+	J, A	+	J, A	J, A
<i>Haemulon sciurus</i>	Predatory vertebrate	Predatory reef fish	+	A	+	J, A	J, A
<i>Pomadasys crocro</i>	Predatory vertebrate	Predatory reef fish				A	
<i>Archosargus probatocephalus</i>	Predatory vertebrate	Predatory reef fish		+		J, A	J
<i>Archosargus rhomboidalis</i>	Predatory vertebrate	Predatory reef fish		+		J, A	J, A
<i>Calamus bajonado</i>	Predatory vertebrate	Predatory reef fish	+	+	+	+	J, A
<i>Lagodon rhomboides</i>	Predatory vertebrate	Predatory seagrass fish	+			A	J, A
<i>Odontoscion dentex</i>	Predatory vertebrate	Predatory reef fish	+	+			+
<i>Micropogonias furnieri</i>	Predatory vertebrate	Predatory seagrass fish	+			J	
<i>Ophioscion punctatissimus</i>	Predatory vertebrate	Predatory seagrass fish					J, A
<i>Bairdiella sanctaeluciae</i>	Predatory vertebrate	Predatory mangrove fish					+
<i>Equetus lanceolatus</i>	Predatory vertebrate	Predatory reef fish					J
<i>Mulloides martinicus</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+	J, A	A	A	J
<i>Pseudupeneus maculatus</i>	Predatory vertebrate	Predatory zoobenthic reef fish		J	A		J, A
<i>Pempheris schomburgki</i>	Predatory vertebrate	Planktivorous reef fish	+	+			
<i>Chaetodipterus faber</i>	Predatory vertebrate	Predatory reef fish				J	+
<i>Chloroscombus crysurus</i>	Predatory vertebrate	Predatory pelagic fish	+			J	+
<i>Chaetodon capistratus</i>	Predatory vertebrate	Predatory reef fish	+	+	+	J	J
<i>Chaetodon sedentarius</i>	Predatory vertebrate	Predatory reef fish	+	+	+		
<i>Chaetodon striatus</i>	Predatory vertebrate	Predatory reef fish	+	J, A	+	J	J
<i>Pomacanthus arcuatus</i>	Predatory vertebrate	Predatory reef fish	+	+		A	S
<i>Pomacanthus paru</i>	Predatory vertebrate	Predatory reef fish	+	+			+
<i>Holacanthus tricolor</i>	Predatory vertebrate	Predatory reef fish	+	J, A			
<i>Abudefduf saxatilis</i>	Predatory vertebrate	Omnivorous reef fish	+	J		J, A	A

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Stegastes adustus</i> (<i>Pomacentrus fucus</i>) (<i>Stegastes dorsopunicans</i>)	Herbivorous vertebrate	Herbivorous reef fish	+	A		A	
<i>Stegastes diencaeus</i>	Herbivorous vertebrate	Herbivorous reef fish	+	+			
<i>Microspathodon chrysurus</i>	Herbivorous vertebrate	Omnivorous reef fish	+	J, A		J	
<i>Abudefduf taurus</i>	Predatory vertebrate	Omnivorous reef fish	+	J, A			
<i>Stegastes leucostictus</i>	Predatory vertebrate	Predatory reef fish	+			J, A	
<i>Stegastes partitus</i>	Predatory vertebrate	Predatory reef fish		+	A	A	
<i>Stegastes planifrons</i>	Predatory vertebrate	Predatory reef fish	+	A	A		
<i>Stegastes variabilis</i> (<i>Pomacentrus variabilis</i>)	Predatory vertebrate	Predatory reef fish	+	A	A		
<i>Chromis cyaneus</i>	Predatory vertebrate	Zooplanktivorous reef fish	+	+			
<i>Mugil curema</i>	Herbivorous vertebrate	Herbivorous pelagic fish	+			J, A	+
<i>Mugil liza</i>	Herbivorous vertebrate	Herbivorous pelagic fish				J, A	
<i>Sphyraena barracuda</i> (<i>Sphyraena guachancho</i>)	Predatory vertebrate	Predatory reef fish	+			J, A	J, A
<i>Sphyraena guachancho</i>	Predatory vertebrate	Predatory reef fish				J	+
<i>Sphyraena picudilla</i>	Predatory vertebrate	Predatory reef fish					+
<i>Polydactylus virginicus</i>	Predatory vertebrate	Predatory zoobenthic seagrass fish				J	+
<i>Bodianus rufus</i>	Predatory vertebrate	Predatory reef fish	+	+		J, A	
<i>Halichoeres bivittatus</i>	Predatory vertebrate	Predatory reef fish	+	J, A, S		+	+
<i>Halichoeres garnoti</i>	Predatory vertebrate	Predatory reef fish	+	J		A	
<i>Halichoeres maculipinna</i>	Predatory vertebrate	Predatory reef fish	+	J			
<i>Halichoeres poeyi</i>	Predatory vertebrate	Predatory reef fish		J			A
<i>Halichoeres radiatus</i>	Predatory vertebrate	Predatory reef fish	+	J, A	+		
<i>Lachnolaimus maximus</i>	Predatory vertebrate	Predatory reef fish	+	+			J
<i>Thalassoma bifasciatum</i>	Predatory vertebrate	Predatory zoobenthic reef fish	+	J, A		A	+
<i>Sparisoma aurofrenatum</i>	Herbivorous vertebrate	Herbivorous reef fish	+	J	+		

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Sparisoma chrysopterum</i>	Herbivorous vertebrate	Herbivorous reef fish	+	+		J, A	A
<i>Sparisoma radians</i>	Herbivorous vertebrate	Herbivorous reef fish	+			J	J, A
<i>Sparisoma rubripinne</i>	Herbivorous vertebrate	Herbivorous reef fish	+	+		J	+
<i>Nicholsina usta usta</i>	Herbivorous vertebrate	Herbivorous seagrass fish					+
<i>Sparisoma viride</i>	Herbivorous vertebrate	Herbivorous reef fish	+	J	+	J, A	J
<i>Scarus coeruleus</i>	Predatory vertebrate	Predatory reef fish					J, A
<i>Scarus guacamaia</i>	Predatory vertebrate	Predatory reef fish	+			J, A	A
<i>Scarus vetula</i>	Predatory vertebrate	Predatory reef fish	+	+	+		
<i>Labrisomus nuchipinnis</i>	Predatory vertebrate	Predatory reef fish		A			+
<i>Malacoctenus triangulatus</i>	Predatory vertebrate	Predatory reef fish		+	A		+
<i>Ophioblennius atlanticus</i>	Herbivorous vertebrate	Herbivorous reef fish	+	A			
<i>Parablennius marmoreus</i>	Predatory vertebrate	Omnivorous reef fish	+	+			
<i>Dormitator maculatus</i>	Predatory vertebrate	Predatory mangrove fish				A	
<i>Eleotris pisonis</i>	Predatory vertebrate	Predatory mangrove fish				A	
<i>Lophogobius cyprinoides</i>	Predatory vertebrate	Omnivorous reef fish				J, A	+
<i>Bathygobius soporator</i>	Predatory vertebrate	Predatory reef fish				A	+
<i>Gobionellus oceanicus</i>	Predatory vertebrate	Predatory reef fish				A	
<i>Acanthurus bahianus</i>	Herbivorous vertebrate	Herbivorous reef fish	+	A		A	J, A
<i>Acanthurus chirugus</i>	Herbivorous vertebrate	Herbivorous reef fish	+	J		J, A	J, A
<i>Acanthurus coeruleus</i>	Herbivorous vertebrate	Herbivorous reef fish	+	A	+	J, A	J, A
<i>Bothus sp.</i>	Predatory vertebrate	Predatory reef fish	+				+
<i>Bothus lunatus</i>	Predatory vertebrate	Predatory reef fish					J, A
<i>Citharichthys spilopterus</i>	Predatory vertebrate	Predatory seagrass fish				J	+
<i>Syphurus plagusia</i>	Predatory vertebrate	Predatory seagrass fish				J	+
<i>Aluterus punctatus</i>	Herbivorous vertebrate	Herbivorous reef fish	+				
<i>Aluterus scriptus</i>	Predatory vertebrate	Predatory reef fish				J	
<i>Balistes vetula</i>	Predatory vertebrate	Predatory reef fish		A, S	+		A
<i>Cantherhines pullus</i>	Predatory vertebrate	Predatory reef fish	+	+			
<i>Lactophryns bicaudalis</i>	Predatory vertebrate	Predatory reef fish					A

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
<i>Lactophrys triqueter</i>	Predatory vertebrate	Predatory reef fish	+	+			+
<i>Diodon holocanthus</i>	Predatory vertebrate	Predatory mangrove fish	+	+		A	A
<i>Diodon hystrix</i>	Predatory vertebrate	Predatory mangrove fish	+	+	+	+	J, A
<i>Canthigaster rostrata</i>	Predatory vertebrate	Predatory reef fish	+	+			J, A
<i>Sphoeroides</i> spp.	Predatory vertebrate	Predatory reef fish	+			+	
<i>Sphoeroides spengleri</i>	Predatory vertebrate	Predatory reef fish	+	+			+
<i>Sphoeroides testudineus</i>	Predatory vertebrate	Predatory reef fish		+		J	J

APPENDIX C:
NUMBER OF SPECIES BENEFITING FROM HABITAT ADDITIONS

The following tables give the number of additional elianite species that would benefit by the addition of subsequent compensatory habitats beginning with one habitat and ending with four habitats. The maximum number of shared elianite reef species is 165.

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Deep Hard Bottom (>10 m)	8
Seagrass	21
Mangrove	8

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Seagrass	54
Mangrove	13
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Deep Hard Bottom (>10 m)	8
Mangrove	20
Seagrass	9

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Seagrass	54
Shallow Hard Bottom (5-10 m)	47
Mangrove	8

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Seagrass	22
Mangrove	8
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Shallow Hard Bottom (5-10 m)	80
Seagrass	21
Mangrove	8

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Seagrass	22
Deep Hard Bottom (>10 m)	7
Mangrove	8

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Shallow Hard Bottom (5-10 m)	80
Mangrove	20
Seagrass	9

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Mangrove	21
Seagrass	9
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Mangrove	41
Seagrass	26
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Mangrove	21
Deep Hard Bottom (>10 m)	7
Seagrass	9

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Mangrove	41
Shallow Hard Bottom (5-10 m)	59
Seagrass	9

Habitat	Additional # of Species
Seagrass	84
Mangrove	15
Shallow Hard Bottom (5-10 m)	59
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Mangrove	68
Shallow Hard Bottom (5-10 m)	81
Deep Hard Bottom (>10 m)	7
Seagrass	9

Habitat	Additional # of Species
Seagrass	84
Mangrove	15
Deep Hard Bottom (>10 m)	24
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Mangrove	68
Shallow Hard Bottom (5-10 m)	81
Seagrass	9
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Seagrass	84
Shallow Hard Bottom (5-10 m)	66
Deep Hard Bottom (>10 m)	7
Mangrove	8

Habitat	Additional # of Species
Mangrove	68
Deep Hard Bottom (>10 m)	29
Seagrass	26
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Seagrass	84
Shallow Hard Bottom (5-10 m)	66
Mangrove	8
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Mangrove	68
Deep Hard Bottom (>10 m)	29
Shallow Hard Bottom (5-10 m)	59
Seagrass	9

Habitat	Additional # of Species
Seagrass	84
Deep Hard Bottom (>10 m)	26
Shallow Hard Bottom (5-10 m)	47
Mangrove	8

Habitat	Additional # of Species
Mangrove	68
Seagrass	31
Deep Hard Bottom (>10 m)	24
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Seagrass	84
Deep Hard Bottom (>10 m)	26
Mangrove	13
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Mangrove	68
Seagrass	31
Shallow Hard Bottom (5-10 m)	59
Deep Hard Bottom (>10 m)	7

APPENDIX D

RESPONSES TO PEER REVIEWER COMMENTS

DOCUMENT REVIEW BY
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**HABITAT SUITABILITY ANALYSIS: COMPENSATION FOR INJURED REEF IN
SUPPORT OF RESTORATION PLANNING FOR THE BERMAN OIL SPILL, SAN
JUAN, PUERTO RICO, JUNE 2005.**

DOCUMENT SUBMITTED BY
MARINE RESOURCES INC.,
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Dr. Gilmore's comments and our responses to them follow the pagination order for the document.

Comment 1:

This habitat suitability analysis (HSA) was based on historical data and some recent extant data for marine habitats along the northern coast of Puerto Rico in the vicinity of the “Berman Oil Spill” site. The HSA was unfortunately limited due to the lack of good quantitative data on the relative abundance of marine organisms along this coast of Puerto Rico. The literature utilized for the analyses appeared to be comprehensive and some additional references have been suggested, but are not totally necessary due to the comprehensive bibliography already constructed. The statistical analyses were appropriate for the data at hand. More detail in techniques of data retrieval and techniques used by the studies examined would have been helpful in determining the nature of the specific faunal data base the authors were able to use. This would have influenced my interpretation of Table B.

Response 1:

We appreciate Dr. Grant Gilmore's comments on the *Habitat Suitability Analysis: Compensation for Injured Reef in Support of Restoration Planning for the Berman Oil Spill, San Juan Puerto Rico*. The overall premise for the Habitat Suitability Analysis (HSA) was to compare species that were documented in injury assessment reports to occur at the injury location with species that were documented in our literature search to occur in the potential Compensatory restoration habitats along the northern coast of Puerto Rico. A list of species likely to have been injured by the grounding incident was compiled from injury assessment documents provided by the Trustees as well as from recent studies conducted along the north coast of Puerto Rico within similar hard bottom habitats. Most of the studies from the north coast provided only species lists and lacked relative abundances of the species encountered. We understand that our species list is not exhaustive and that other species may utilize the injured and compensatory restoration habitats; the HSA included only species that were documented in our literature search.

Comment 2:

Page 4 - Elimination of zooplanktivores from the HSA may not be justified for an oil spill event as they are likely to have been directly influenced by surface oil films due to their typical association with surface waters. These species are not always considered highly migratory, particularly atherinids (seagrass, reef, and mangrove) and poeciliids (mangrove). Although engraulids and clupeids have a greater daily range, they also may associate with particular regions of high productivity for prolonged periods of time (bay and river mouths, upwelling zones). It would be interesting to know their distribution, relative to the high energy zones of the north coast of Puerto Rico and San Juan harbor, as there are several potential nutrient and planktonic enrichment zones in this area which have permanent zooplanktivore populations that could have been directly impacted by the oil spill.

Response 2:

We agree with Dr. Gilmore's comment that zooplanktivores are particularly susceptible to oil spills. Studies of Pacific herring populations in Prince William Sound following the *Exxon Valdez* Oil Spill provide clear proof of impacts to zooplanktivores. However, the purpose of our HSA was to evaluate compensatory habitats for the injury that occurred due to the physical damage to the reef structure from the grounding, not the impacts of the release of oil. Because the injured habitat and the habitats considered appropriate for compensation are benthic (bottom), species expected to be impacted by loss of reef habitat and addition of new benthic habitat are demersal (bottom oriented) fish and herbivores. This was our original basis for excluding these fish from the analysis. In reality, the number of fish species excluded from the analysis (2 zooplanktivores) was small and their inclusion would not alter our conclusions.

Comment 3:

Page 9 - It is not clear how the "likely injured" categories for impacted organisms were determined.

Response 3:

Organisms were designated as "likely injured" if the damage assessment reports provided by the trustees documented their occurrence in the impacted area or that the organisms were injured by the incident.

Comment 4:

Page 11 - One important group of surface predators were not mentioned, and were likely to be the species most impacted by the oil spill. These are the needlefishes, belonids, halfbeaks, hemiramphids, and flying fish, exocoetids that have an intimate association with the water's surface and represent a significant biomass in tropical coastal waters. Halfbeaks are omnivores and herbivores during diurnal periods, predators (zooplanktivores) at night. Various species associated with seagrass (*Hyprhamphus unifasciatus*, *Strongylura timucu* & *S. notata*), mangroves (*Strongylura notata*) and reef formations (*Hemiramphus* spp., *Tylosurus corcodilus* and *T. acus*, *Exocoetus* spp, *Parexocoetus* spp.). Halfbeaks and needlefishes are more likely to be residential.

Tarpon are obligate air breathers as juveniles, first ten years (1 m in SL) , and therefore, are highly likely to have come in contact with oil during this event . Even though they may be considered transients, they do duel in areas of particular prey abundance and stay in certain areas for months at a time. They could have been significantly impacted by the oil spill. Young tarpon are likely resident in inshore coves, mangrove and seagrass ecosystems for months at a time.

Response 4:

Again, we recognize that surface feeding species are susceptible to the effects of oil spills, but not so much to the physical damage to the reef structure from the grounding. Several of the above mentioned fish were documented to occur in the area and are therefore included in our analysis. The surface predators were not discussed in the text because we focused on the species expected to be impacted due to the loss of reef habitat caused by the physical damage to the reef structure, not the impacts of the release of the oil. We recognize that there are many species that may occur in the area, but lack published validation of their occurrence. To maintain the rigor of our analysis, we restricted our analysis to those species that were documented to occur in the study area.

Comment 5:

Page 17 - Since high energy, shallow hard bottom habitat, <5-10 m deep is the primary habitat of concern the literature by Ken Lindeman for similar high energy nearshore rock reef formations in east Florida is particularly valuable in addressing the impacted fauna.

Response 5:

Lindeman and Snyder (1999), listed in Appendix A, was reviewed and used for background information and cross referencing of species that were documented from the north coast of Puerto Rico. Due to the location of the study, the document was not cited in the text.

Comment 6:

Table 9 - Since many species are actually omnivores, was this ever considered as a category?

Response 6:

Dr. Gilmore's comment is well-supported; many of the species we classified as predatory or herbivorous show some degree of omnivory (i.e. feeding at different trophic levels). However, the designation of species as omnivores is highly subjective. Further, the majority of omnivorous species are primarily predatory; the addition of an omnivore classification would simply subdivide this group. While we did not perform this separate analysis, it is unlikely that this subdivision would greatly effect our conclusions.

Comment 7:

Page 19 - I agree that the seagrass (possibly algae), hard substrate (artificial reef) mosaic may be the optimum compensation scenario. I suggest that a structure that mimics the original reef configuration be the best to utilize. I did not see illustrations of the potential hard reef habitat form that would be used. This is very important. It would also be advantageous to place this compensatory restoration site as close to the original site as possible. The reason for this is that an increasing literature point to patchy distribution of fish and invertebrates is relatively

homogenous habitats such as seagrass or mangrove communities. This is often due to preferred local hydrological, oceanographic or geological/topographical conditions.

Response 7:

We agree that the artificial structure should mimic the natural reefs occurring within the area and be placed as close as possible to the injury site. The configuration of the artificial structure itself is beyond the scope of the current document and was therefore not included. Due to the conditions at the injured reef site, placement of an artificial reef is not considered feasible. Therefore, the compensatory restoration habitat should be located as close as possible to the injured habitat to best mitigate for the lost resources of the injured reef habitat.

Comment 8:

PRIMARY LITERATURE - Section A-2 - Suggest adding more Stoner et al Puerto Rican literature, J. Kemmel (PR & Fla.), J. Serafy et al recent paper on mangrove communities in SE Fla., possibly these RGG pubs would be helpful

- Gilmore, R.G. and S.C. Snedaker. 1993. Chapter 5: Mangrove Forests pp 165-198 In W. H. Martin, S.G. Boyce and A.C. Echternacht (eds.) Biodiversity of the Southeastern United States: Lowland Terrestrial Communities. John Wiley & Sons, Inc., Publishers, N.Y. 502 pp.
- Gilmore, R.G. 1977. Fishes of the Indian River lagoon and adjacent waters, Florida. Bulletin of the Florida State Museum 22: 101-147. (lists species by relative habitat association)

Response 8:

We appreciate your suggestions for additional literature. We searched for additional Stoner et al. documents, as well as literature from Kimmel, and have looked over the Gilmore (1977) paper. As part of the initial literature search, MRI contacted Dr. J. Kimmel requesting any relevant literature that focused on the north coast of Puerto Rico. Dr. Kimmel reviewed our literature cited and could not provide any additional references. We conducted a specific key word literature search in which this additional literature did not appear and due to constraints in time, have decided not to incorporate these papers into the final document.

Comment 9:

B-12 Suggest using “shark” for Negaprion as it is a shark. However, since elasmobranchs are fishes, fish can be used correctly for the rays listed, Dasyatis sp, Aetobatus, etc. as well as for the sharks.

Response 9:

The organism description for Negaprion has been changed to predatory shark rather than predatory fish. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not be influenced.

Comment 10:

B-12 Megalops atlanticus is a mangrove and seagrass species as well as pelagic reef species.

Response 10:

To maintain the rigor of our analysis, we restricted our habitat characterizations to those that were documented in the literature search. *M. atlanticus* is listed in Table B as a mangrove and seagrass species, but we did not come across any documentation for the reef habitat.

Comment 11:

B-12 *Albula vulpes* is a “seagrass” fish.

Response 11:

The organism description for *A. vulpes* was changed from predatory reef fish to predatory seagrass fish. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 12:

B-12 *Anguilla rostrata* is NOT a “pelagic” fish and is questionable as a mangrove associate.

Response 12:

The designation was changed to benthic fish, but it was kept as a mangrove associate as cited by Austin (1971). This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 13:

B-12 *Mycrophis* spp....What is a “zoobenthic” reef fish and why are the ophichthyids not on this list in this category? Several eel species are missing from the list.

Response 13:

Zoobenthic feeders are predatory fishes which feed specifically on vertebrates and invertebrates that live within or rely directly on the substrate regardless of hard or soft bottom habitat type. To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 14:

B-12 *Harengula jaguana* and *H. clupeola* should be on this list.

Response 14:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 15:

B-13 *Anchoa lyolepis* is missing.

Response 15:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 16:

B-13 It is highly unlikely that *Strongylura marina* (warm temperate-temperate Atlantic continental species) occurs in Puerto Rico and highly likely that it is an old record for a misidentified *Strongylura timucu*. Adult *S. timucu* and *S. notata* are common in mangrove and seagrass habitats.

Response 16:

***S. marina* was removed from the species list. *S. timucu* and *S. notata* were not documented in our literature search as occurring in seagrass beds and therefore the habitat characterizations were not adjusted. Removing one fish from the analysis would not influence the outcome of the analysis.**

Comment 17:

B-13 *Hemiramphus balao* should be considered for the list.

Response 17:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 18:

B-13 How come *Holocentrus* spp and *Plectrypops* are reef fish and *Myripristis* is “zoobenthic”?

Response 18:

The recommended changes to the organism descriptions have been made in Table B. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 19:

B-14 *Centropomus mexicanus* has also been recorded from Puerto Rico ..published.

Response 19:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 20:

B-14 What about *Epinephelus itajara*, which is a reef and mangrove associate?

Response 20:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat or in any of the compensatory restoration habitats. Only three additional species were suggested that occurred in two of the four compensatory habitats. These additions would not change the outcome of the analysis and were therefore not incorporated.

Comment 21:

B-14 No *Hypoplectrus* spp. were listed and they undoubtedly occur on these reefs as well as in certain mangroves (recorded from mangroves in Cuba).

Response 21:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat. Only three additional species were suggested that occurred in two of the four compensatory habitats. These additions would not change the outcome of the analysis and were therefore not incorporated.

Comment 22:

B-14 What about *Apogon pseudomaculatus*...reef associate?

Response 22:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 23:

B-14 *Caranx barthelomaei* should be spelled *C. bartholomaei*.

Response 23:

The spelling was corrected for this species.

Comment 24:

B-14 What happened to *C. chrysos*?

Response 24:

Although *C. chrysos* is a reef associated fish, they were only documented as occurring along the north coast of Puerto Rico in one of the studies found during our literature search. The stations at which *C. chrysos* was documented were offshore and not associated with hard bottom habitats. Since this species was not documented in our literature search to occur in the injured habitat, it was not included in the species list.

Comment 25:

B-15 The mojarras, geriidae, are listed as reef microcrustacean consumers when they are actually benthic sediment predators feeding on polychaetes and a wide variety of other benthic invertebrates (“zoobenthic”). I would only consider *Gerres cinereus* as a reef species, possibly *E. lefroyi*. *E. gula* is primarily a seagrass species, *Dipterus* spp. estuarine and freshwater soft sediment associates also occurring in mangroves commonly. *E. argenteus* and *E. melanopterus* occur in high energy beach situations. *E. harengulus* is not listed, but is the most common estuarine and freshwater tributary mojarra in the sub-tropical and tropical western Atlantic (previously misidentified as *E. argenteus*).

Response 25:

The above species were incorrectly labeled as microcrustacean consumers. The table has been corrected to properly characterize them as predatory zoobenthic fish. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 26:

B-16 *Diplodus argenteus* is not on the list, but should be as a omnivorous reef fish. Most of the sparids are decidedly omnivorous. Other species of *Calamus* have been omitted for some reason.

Response 26:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat. These recommendations would not change the functional group in which the organisms were characterized; therefore the changes were not incorporated.

Comment 27:

B-16 *Bairdiella sanctaeluciae* is definitely a reef fish, but most often associated with tropical algal reef formations rather than coral reef formations. Continental juveniles are most common in seagrass not mangroves.

Response 27:

The recommended changes to the organism description have been incorporated. This recommendation does not change the functional group in which the organisms were characterized and therefore does not influence the outcome of the analysis.

Comment 28:

B-16 What happened to the other *Equetus* species, *Parequetus* as well?

Response 28:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 29:

B-16 What happened to *Holacanthus ciliaris* and *H. bermudensis*?

Response 29:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 30:

B-17 *Sphyraena* guachancho and *S. picudilla* should also be listed for “reef” formations.

Response 30:

To maintain the rigor of our analysis, we restricted our habitat characterizations to those that were documented in the literature search; therefore this recommendation was not incorporated.

Comment 31:

B-17 *Halichoeres bivittatus* occurs in seagrass as juveniles & so do *H. maculipinna*.

Response 31:

To maintain the rigor of our analysis, we restricted our habitat characterizations to those that were documented in the literature search; therefore this recommendation was not incorporated.

Comment 32:

B-17 What happened to *Doratonotus megalepis* a common reef and seagrass associate?

Response 32:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat or in any of the compensatory habitats. Only three additional species were suggested that occurred in two of the four compensatory habitats. These additions would not change the outcome of the analysis and were therefore not incorporated.

Comment 33:

B-17 No *Cryptotomus roseus*?

Response 33:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 34:

B-18 Both *Labrisomus nuchipinnus* and *Malacoctenus triangulatus* occur commonly in high energy rock reefs at depths 0-5 m in Florida as assume that they would have been at the Grounding Site in PR. They also can occur in mangroves and seagrass in decidedly marine conditions, not well within estuaries.

Response 34:

To maintain the rigor of our analysis, we restricted our analysis to those species that were documented to occur in the study area and our habitat characterizations were restricted to those that were documented in the literature search; therefore this recommendation was not incorporated. These species are listed in the table as likely to occur within the injured area as documented in our literature search, but were not documented as injured in our documents.

Comment 35:

B-18 What happened to Bathygobius curacao, Ctenogobius spp, particularly C. smaragdus and C. stigmaturus, Gnatholepis thompsoni, Elacatinus spp, and all Coryphopterus spp.? It appears that the reef, seagrass and mangrove gobiids have been underestimated.

Response 35:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 36:

B-18 What happened to Monocanthus spp. and Stephanolepis spp.? These latter species are quite common in various tropical habitats.

Response 36:

To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

NOTE: Relative to these comments on Table B, I realize the authors have apparently had little literature for this region of Puerto Rico on which to depend. However, my comments are based on what we do know of these species elsewhere in Puerto Rico, Cuba, the Windward Islands, South, Central and tropical/subtropical North America.

A major constraint of this Habitat Suitability Analysis was the lack of quantitative data for the hard bottom habitat of the northern coast of Puerto Rico. Several species lists from various studies conducted along the north coast and from injury assessment reports for the *Morris J. Berman* grounding incident were utilized to compile the likely injured species list in Table B. Our literature search encompassed information from the Caribbean and south Florida in addition to literature from Puerto Rico. The north coast of Puerto Rico is a high energy, low-relief, hard bottom habitat dominated by soft corals and mixed algal assemblages which varies greatly from the coral reef dominated habitats throughout the Caribbean, southern Florida and the southern coast of Puerto Rico. Due to the differences in habitats, we did not include fish from the southern coast of Puerto Rico or surrounding areas if they were not also documented from the northern coast of Puerto Rico.

APPENDIX E

RESPONSES TO TRUSTEE COMMENTS

Comment 1:

Table B. Please define how the species assemblage included in the “Grounding Site 0-5m” was obtained. Is this solely a list of species provided from Trustee Documents or did this habitat receive as thorough a literature review as the other habitat types.

- If this column represents a thorough literature review then we would recommend re-labeling the column name as “eolianite reef” – since “Grounding site” may give the impression that we are only looking impact site –potentially after grounding and not in its prior condition. This distinction should also be made under Section 2.0 Methods and elsewhere though the document
- If this column only represents species from Trustee documents, then it doesn’t seem appropriate that any other species would be included for the other habitat types. This is because the Trustees are interested in how other potential habitat types may provide habitat for the exact same set of species as those that were found on the reef.

Response 1:

In Table B the species documented as occurring in the column labeled “grounding site” were compiled from a thorough literature review including damage assessment studies provided by the Trustees. The damage assessment documents contained species lists for unimpacted areas similar to the habitat injured by the *Morris J. Berman* grounding incident. Therefore, we have changed the column heading to “Eolianite Reef” since the species documented within this column are found in an eolianite reef habitat. This distinction is made in SECTION 2.0 and is consistent throughout the document.

Comment 2:

Use of a similarity index is not really the appropriate approach. By including species from other habitat types that are not found on the “injured habitat type”, you are automatically driving the similarity indices further apart. In other words, what the Trustees are interested in is “Given the species that exist on the injured habitat type, what other habitats will provide them benefit.” The Trustees are not interested in how similar the habitats are – but in how other habitat types may provide service to species found on the injured (eolianite) reefs.

- The use of a similarity index could still be applied looking only at the similarity of species between the different habitats – only for species that exist on the injured habitat type.
- Alternatively, a simple matrix which includes “Total number of species on injured habitat type”, and a break down of the habitat type with the highest number of overlapping species, then the habitat type with the most number of species matching the injured habitat but not captured by the first habitat. See example Table. Using this approach, up to 16 different tables could be generated, each one representing a different order of the compensatory habitat types as represented in the last column of the example table below. In this manner, the Trustees can choose a mosaic of habitats with some logic behind the combination that benefits the most species.

Table. # species utilizing Eolianite reef that also utilize other habitat types.

Habitats	Total # species matching Eolianite Reef	# species of interest unique to one alternative	# of unique species to benefit by adding on the next alternative
Eolianite Reef	100	(10 not found in any other habitat types)	
Hard Bottom 5-10	60	20	60
Hard Bottom > 10	40	2	2
Mangroves	25	10	15
Seagrass	20	3	5

Response 2:

The Habitat Suitability Analysis was modified to include only the 183 documented eolianite reef species as suggested by the Trustees.

We have included a group of matrices to help the reader better understand the similarities and differences between the species composition of eolianite reef and compensatory habitats. The tables show the number of eolianite species also documented in the compensatory habitats and in the two-habitat and three-habitat compensatory mosaics. The number of species to benefit by the addition of another compensatory habitat type is provided in APPENDIX C.

Comment 3:

The conclusions are not necessarily supported by the analysis that was completed. “No single habitat was identical to the injured habitat for all four services; therefore a mosaic approach of restoration/creation of more than one habitat may be the best alternative.”

- The analysis that was completed was a similarity comparison that looked at presence/absence of species in the individual habitats – not their mosaic ability to compensate. In order to draw this conclusion, it would be necessary to say something about the ability of the “preferred” habitat to compensate and given that level of compensation, something about the 2nd habitat, and given that level of compensation, something about the 3rd habitat.
- Artificial reefs are specifically identified as a reasonable compensatory restoration alternative yet artificial reefs are not included in the similarity analysis along with hard bottom 5-10m, hard bottom >10m, seagrass or mangrove habitats. In order to justify including artificial reef under the conclusion, artificial reef should be treated as a separate habitat type (i.e., a fifth habitat type) in order to provide a reasonable basis for this conclusion. Otherwise, a separate analysis demonstrating that hard bottom habitats, specifically those used in the analysis, are sufficiently similar to artificial reef is required to demonstrate that hard bottom habitat and artificial reefs are interchangeable. Looking through the literature citations, several artificial reef references are included. Indeed the SOW provides the latitude to look at other habitats (i.e., SOW III, B, 2, fourth bullet: “analysis of other habitats that provide the same or comparable type and quality of habitat services to faunal communities associated with the injured habitat including, but not

limited to, mangroves, seagrass beds and hard bottom habitats (at various depths up to 90 feet)"

Response 3:

Based on the comments and issues provided in Comment 3, MRI has assembled TABLES 11-13 in SECTION 4.0. The purpose of the tables is to present the number of species that are shared between each compensatory restoration habitat and the eolianite reef habitat. The compiled tables illustrate the ability of the preferred mosaic compensatory restoration to compensate for the highest number of species found within the eolianite habitat.

In the second comment, the NOAA reviewers requested that we demonstrate or document the high relational similarity or interchangeability of artificial reef habitats to the shallow water eolianite reef habitat. No quantitative or qualitative data regarding artificial reefs on the northern coast of Puerto Rico was discovered during the literature search effort. Based on the absence of data we could not include artificial reefs as a compensatory habitat in our similarity analysis. In SECTIONS 2.0 and 4.1.1 MRI and Dr. Sean Powers have expanded on the functional application of artificial reefs to recruit and support ichthyofaunal and invertebrate assemblages that are highly similar if not more diverse than local natural reefs systems. The literature presented in these sections demonstrates how effective artificial reefs can be as a compensatory habitat if constructed in an appropriate manner.

Comment 4:

Throughout the document, the term mitigation and/or mitigation habitat is used. The appropriate term, in the context of natural resource damage assessment, is compensatory restoration. The term mitigation should not be used in this document.

Response 4:

The term mitigation and/or mitigation habitat was changed to compensatory restoration and/or compensatory habitat throughout the document.

Comment 5:

Figure 2. under Step II, uses the term "listed species". Because the term "listed species" has meaning under the Endangered Species Act, an alternative term should be used.

Response 5:

The term "listed species" in FIGURE 2 was changed to documented species.

Comment 6:

What is the purpose of Figure 3.? Primary Impact Area and Secondary Impact Area designated but the injured eolianite reef was a discrete area impacted by the barge grounding. If the large polygons identified as Primary and Secondary Impact areas and depicted by Figure 3. characterize the area of oiling, then what is the purpose? Similar to HSA Response #4 to the Reviewer comments, the analysis should focus on the eolianite reef, a physical loss not a loss due to oil exposure. Figure #3, which is also used on the front cover, gives an impression of an oil exposure area. Either eliminate the figure or explain its relationship to the analysis.

Response 6:

We agree and have removed the Primary and Secondary Impact Area designations from the figure. We have kept the figure without the impact areas to provide the reader with a map to orient themselves with the area in which the grounding occurred.

Comment 7:

Section 2.0 Methods, second paragraph, #3 "... greater than > 10 m;" This is redundant. It should read either "greater than 10 m" or "> 10 m".

Response 7:

The greater than symbol (>) has been removed.

Comment 8:

Section 2.0 first numbered item, Strike “injured” per comments above.

Response 8:

All references to the “injured” habitat throughout the document have been changed to “eolianite reef habitat”.

Comment 9:

Section 2.0 Second Paragraph ; Is the assumption that an artificial reef , after a brief period of succession (~5 years) would mimic the natural reef system supported by the data collected during the literature search? Do the artificial habitats described in the literature search mimic the natural hard bottom areas to such a degree that the fish associated with the artificial reefs can be assumed to be associated with the various hard bottom habitats (i.e., 0-5m, 5-10 m & > 10 m)? If not, then artificial reef ought to be listed as a separate habitat and compared to the other four compensatory restoration alternatives.

Response 9:

A discussion concerning artificial reef providing ecological services similar to natural hard bottom has bee included in the revised text SECTION 2.0.

Comment 10:

Section 2.2 Habitat Suitability Analysis, first paragraph, 2nd sentence: recommend adding “either directly or indirectly” after “...species likely injured...”

Response 10:

The sentence has been changed to: The species that were documented to utilize the eolianite reef habitat were considered to be species either directly or indirectly injured by the grounding incident.

Comment 11:

Section 2.2 Habitat Suitability Analysis, first paragraph, 4th line: "Trustees" is misspelled.

Response 11:

The spelling has been corrected in the text.

Comment 12:

Section 3.2: A general description of the services provided by eolianite reef at the beginning of the document would be helpful to frame the analysis and conclusion. Currently, the functional groups serve as a metric of services, but a concise description of the services provided by the eolianite reef is lacking. Recognizing there is little quantitative data, is it possible to provide a breakdown of the expected community structure of the reef in regards to the functional groups (i.e., % producers, % structural animals etc.,) as part of the service description?

Response 12:

SECTION 1.2 has been expanded to provide an introductory description of the eolianite reef habitat. A general description of the services provided by an eolianite habitat is found in the 4th paragraph of SECTION 2.0 and a thorough discussion of the eolianite reef habitat and the organisms within each service category is provided in SECTION 3.3.

Comment 13:

Section 3.2 3rd paragraph first sentence: Need to explain Figure 3 better. Specifically, what is meant by the Primary and secondary impact areas?

Response 13:

As per Comment 6, the impact areas have been removed from the figure.

Comment 14:

Section 3.2 3rd paragraphs, Sentence beginning with “The most commonly affected biota...” This statement is confusing when compared with the last sentence in the 1st paragraph of Section 3.3 that begins with “Faunal groups with the most species likely injured...”

Response 14:

The statement made in the 3rd paragraph of SECTION 3.2 referred to the organism injured by the grounding incident and the subsequent oil spill whereas the sentence in SECTION 3.3 referred to organisms documented within the eolianite reef habitat only. This was clarified in the document.

Comment 15:

Section 3.3 Appendix B includes more than indicated in the first paragraph of 3.3 for instance a description of the faunal communities is also included.

Response 15:

APPENDIX B is initially described in SECTION 2.2. SECTION 3.3 was expanded to provide a more thorough description of the APPENDIX B table.

Comment 16:

Section 3.3.1 Primary Producers, 4th line from the bottom should read, "Halimeda spp., calcareous green algae..." since spp. indicates more than one species.

Response 16:

The correction was made in the text.

Comment 17:

Section 3.3.1 No mention that primary producers provide food as a service.

Response 17:

SECTION 3.3.1 was expanded to give a general description of the services provided by primary producers and provides specific descriptions of primary producers in the eolianite reef habitat.

Comment 18:

Section 3.3.2 Second Paragraph, last sentence – Were the 10 species documented likely injured determined by Trustee documents or were they associated with the eolianite habitat as determined by the literature search? (As a general comment similar to this specific comment, it may be clearer to the reader to identify which species were documented as injured during the assessment and which are included because of the literature search.)

Response 18:

The sentence was changed to more clearly explain that the 12 species (the number was incorrect after a recount) were documented in the eolianite habitat from the literature search and were therefore either indirectly or directly injured by the grounding.

Comment 19:

Section 3.3 & 3.4 According to Section 2.2, species are assigned one of four service categories (primary producers, structural animals, herbivores and predators) so the headings for Section 3.3.3 (Motile Invertebrates) and 3.3.4 (Vertebrates) doesn't relate to a functional group as described in 2.2

Response 19:

SECTION 3.3 has been reorganized to reflect the service categories as described in SECTION 2.2. The revised portions of SECTION 3.3 are now labeled as follows:

**SECTION 3.3.3 Herbivores;
SECTION 3.3.3.1 Invertebrates;
SECTION 3.3.3.2 Vertebrates;
SECTION 3.3.4 Predators;
SECTION 3.3.4.1 Invertebrates
SECTION 3.3.4.2 Vertebrates**

SECTION 3.3.3 and 3.3.4 provide a general description of the services provided within the eolianite reef habitat by the identified service category. The invertebrate and vertebrate subsections provide specific examples of the services provided by the identified faunal groups within the eolianite reef habitat.

Comment 20:

Section 3.3.3 Motile invertebrates, final line recommended addition, "...important commercial species in Puerto Rico, and is listed in Appendix II of CITES as Threatened."

Response 20:

Recommended addition was included in the document.

Comment 21:

3.4.2 Structural Animals Isn't it logical to include all species that provide structure (algae, seagrass...) instead of just animals that provide structure?

Response 21:

In SECTION 3.4.2 we have included that many primary producers also contribute to the structural complexity of the habitat but explain that they are not included in the analysis as structural animals because their primary role is primary production. We do discuss in SECTION 3.3.1 that some primary producers also provide structure as a habitat service.

Comment 22:

3.4.2. Question regarding plot. Does having more structural animals make a habitat more structurally complex? Seagrass is very structurally complex yet probably has far less structural animals...

Response 22:

Structural complexity of a habitat is not directly correlated to the number of structural animals. For example, seagrass and mangroves create structurally complex habitats with a relative few species of structural animals.

Comment 23:

3.4.3 Is a habitat service of the Herbivores to be prey?

Response 23:

This service of herbivores is explained in SECTION 3.3.3.

Comment 24:

Figure 3. legend repeats redundancy: "less < 0.1". Should be less than 0.1 or < 0.1.

Figure 4. legend same problem as Figure 3.

Figure 6. legend same problem as Figure 3.

Response 24:

The legend has been changed to remove the redundancy in all of the aforementioned figures.

Comment 25:

Table 8. correct scientific name is: Epinephelus gutatus for Red hind.

Response 25:

The spelling was corrected in TABLE 8.

Comment 26:

In the paragraph following Figure 7, I wonder whether we could modify the first sentence to read, "A desirable coupling may be the restoration * or protection * of seagrass beds..."

Response 26:

Sentence has been changed to use the term compensatory restoration, which encompasses all possible options for the Trustees.

Comment 27:

Further down in that same paragraph, there are unnecessary italics following "Chaetodon capistratus".

Response 27:

Unnecessary italics were removed from the text.

Comment 28:

In Appendix B, Page B-4, three species of seagrass are included as primary producers within seagrass habitat. Is it appropriate to include the species that makes up the habitat in the similarity index?

Response 28:

All of the species documented in the habitats can be considered to make up the habitat. We have included seagrasses because they are important primary producers in the seagrass habitat.